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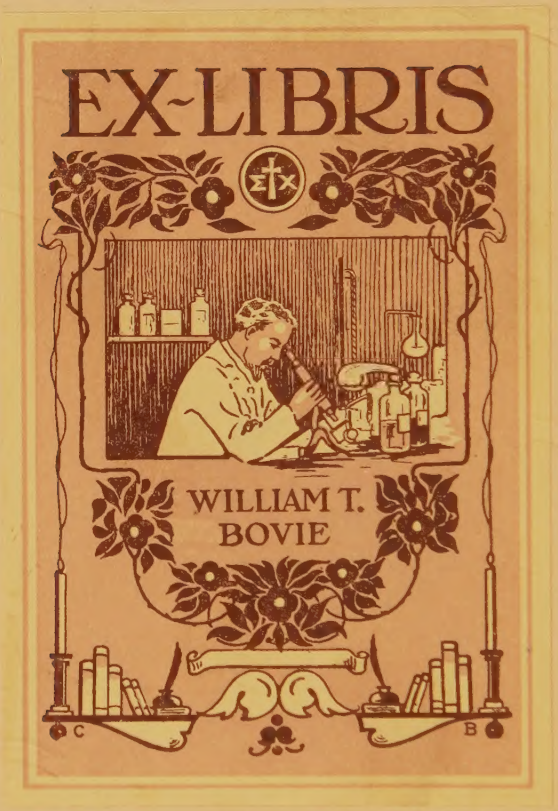
IN NEUROLOGY
ERNEST H. PASQUÉ

2ND. BOOK
NEW CONCEPTS OF PHYSICS
CALVIN SAMUEL PAGE



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A RESEARCH IN ELECTRO-BIOLOGY

1ST BOOK

The Electro-Chemical Factor in Neurology

A Research in Electro-Biology

ERNEST H. PASQUÉ
Vice-President Atomic Research Association

2ND BOOK

New Concepts of Physics

CALVIN SAMUEL PAGE
Author of *"Science of Physical Phenomena"*
"The New Physical Philosophy"
"Rx the Life Atom"

PUBLISHED BY
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DEDICATED

TO THE

PROGRESS OF SCIENCE

AND

THERAPEUTICS

C.C.371.

Knowledge is the *conscious understanding* of the *facts of nature.*

All the *facts of nature* are not known yet.

Only such *facts* as human intelligence can *identify,* have *definitions* in *exact science.*

The limitations then in *exact science* are the *number* of *facts known* and the *stage* or *extent* of *development* of *human intelligence* to identify and comprehend the *known facts.*

Knowledge, facts, exact science are ever evolving and growing conditions in the conception of *human intelligence.*

The *Truth* is then: The established relation which the facts of nature sustain to each other and to the individual intelligence of man.

T. K.

FOREWORD

IN writing and compiling the first book, "The Electro-Chemical Factor in Neurology," it has been the author's aim to only use authentic standard text material and to select and present this material in such a way as to make its final conclusion to the point and the logic of the findings acceptable to any open-minded student of physiology, biology or any of its allied sciences. It is not the intention of this work to promulgate any particular trend, tendency or branch of any particular school of healing, but it is intended to draw a definite and concise picture of electro-biological functions from the very beginning, up to and including the very latest discoveries of electron actions and their electro-chemical connections with the functioning of the living human organism and Neurology in particular.

The writer believes there is an intense interest and a need which will justify the reading of this study of the greatest subject for human conjecture. He also ventures the prediction that from the study and knowledge of electro-chemistry and its relation and action in Neurology, in the human organism as a whole, most startling results will in the very near future develop and eventually revolutionize completely our now prevalent modes of treating disease.

Apologies are necessary for the very briefness with which some subjects have been treated. Volumes can be and have been written on each one of them and many others that of necessity have not even been mentioned here.

It is, however, hoped that this work will serve its

purpose, which after all is to arouse the interest and attention of those worthy men in the healing profession who are seeking for a more effective medium with which to aid and alleviate human suffering from the ravages of disease.

Needless to say it is the accumulative knowledge resulting from the work of hundreds of scientific investigators who have devoted their whole lives to the study of the sciences under discussion, which has made it possible to present and compile this book.

Perhaps the most startling assertions made in this first book are to be found under the chapter of Synapses and the General Summary, and it is hoped that these findings will be of as great an interest and importance to the reader as I see them to be.

In presenting the second book, "New Concepts of Physics," by Calvin Samuel Page, I feel an explanation is in place. It was not until after the writer had studied "Page's Physics" that a clear understanding of electrobiology, heat-light, magnetism, etc., and especially the phenomena of an even body temperature, dawned upon him, and slowly began to take shape. The absolute helplessness with which the practitioner is at times confronted, in the case of progressive infections, fevers and other so far incurable conditions, as well as the general dissension of opinion between the different healing cults, prompted me to investigate and search the known sources of wisdom, hoping to find a common foundation, a science that would answer all physical phenomena, in such a way that it would furnish an explanation for the mechanics of all normal and abnormal functional activities. At the same time I hoped that this might be possible of accomplishment without leaving the realm of established, recognized, and known

science. This, I think, I have been able to do. But I must admit that it was mostly through the understanding of Page's "New Concept" of light, magnetism, gravitation and heat, that I was able to translate the "regular physics" in a way so that it too will give a logical foundation for electro-biology or the "Electro-Chemical Factor in Neurology."

After summing up the extensive work done by those scientists, who have investigated and formulated our present day Electron conception and the work of Calvin Samuel Page, I have, in order to facilitate my understanding, compared and exchanged the electron with Rx and vice versa. At once it was obvious that what one calls the electron must be the same than what the other terms Rx. While the former is supposed to reside inside the atom the latter is outside the atom. In either case they are the actor or energy which holds the atom in molecular combination. In short the final results appear to be the same. So that it seems to depend largely upon the view one takes, the philosophy which has been accepted more generally or the philosophy one is used to, that would determine one's decision as to Electron or Rx. It tempts me to compare it to a wonderful scientific treatise, one written in longhand, the other in shorthand or some other unknown simplified system of hieroglyphics; in the end both mean the same. When I consider the tremendous tensile or compressible strength of steel, I do not have to stretch my imagination so far to accept Page's two fundamental energies, atomic cohesion and Rx repelling, as I must in order to accept the prevalent thesis that the atom is hollow, with the electrons vibrating inside of it, with spaces in between them, larger than the distance between sun and earth, proportional with size.

In spite of that, Biology, leaving out Psychology and Metaphysics, functions rationally and in a way which our poor physical concepts or limited capacities can understand. If we can know how it functions normally and in detail, can we then not also know what has happened when it functions abnormally? And should it then not be possible to know what to do in order to restore normal functions?

I have endeavored in this work to explain the normal functions of the vital factors in the human organism, not so much in every detail, as in principle.

But I want the reader to also have the benefit of Calvin Samuel Page's knowledge and works. For this reason the Atomic Research Association has arranged with Prof. Page for permission and rights to print and publish in this book such of his Philosophy and discoveries as might be useful for a complete mental conception of the subject matter.

Ernest H. Pasqué.

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CHAPTER I

ELECTRON DEFINITIONS

ACCORDING to the investigations of Zwaardemaker, the inventor of the new term "bio-radioactivity," the human body contains on the average forty grams of potassium, which emit 80,000 beta particles per second. These particles consist of electrons, moving with a mean velocity of more than a hundred thousand miles per second. They are darting through all parts of our bodies with this tremendous speed, but the length of their flights is all but infinitesimal, owing to the continual interception of their course by the other components of the tissues. But the shock of every encounter that interrupts the flight of a beta particle instantly gives rise to a minute flash which proclaims the formation of an X-ray, or a little sheaf of X-rays.

Let us see a little more definitely how this is accomplished. Most all physical experiments with nerves in connection with electricity have been made with galvanic or voltaic currents of considerable quantity in comparison with the actual electrical potential of the human system. While it has proven to do certain things it is by no means absolutely convincing that the same things happen during life in the human body. In fact they do not. Both the current and the action are entirely different. We learn that certain electric stimulus along a nerve trunk will produce certain muscular contractions or reactions which are, however, very indefinite and nothing like what takes place in the human organism during life. In order to have a clearer conception of the complex action, chemical, thermic,

osmotic, metabolic, integrating, and disintegrating, we must take into consideration electrolysis and electrochemical action, since in the final analysis these are the fundamental factors which through the presence, quantity and kind of electricity perform all changes. For some definite proof in this we can go back as far as 1868. In some papers and actual experiments made by Herman Kolbe at that time (given before the Alembic Club, Edinburgh, Scotland, and published by the University of Chicago Press), a summary of researches on the electrolysis or organic compounds, we can briefly quote this: "The facility with which, particularly certain acids, resisting in a moist form the most powerful oxidizing processes, are decomposed under these electrolytic circumstances, appears to point to electrolized oxygen as one of the most valuable oxidizing agents which are at the disposal of the chemist. Its application in chemical decompositions accquires additional importance *since its intensity may be varied, either by concentrating and heating the liquid, or by increasing or diminishing the mineral elements producing the electro-current. Starting from the hypothesis that acetic is a conjugated compound of oxalic acid and the conjunct methyl, I consider it, under these circumstances, not at all improbable that electrolysis might effect a separation of its conjugated constituents, and that, in consequence of a simultaneous decomposition of water, carbonic acid as a product of the oxidation of oxalic acid might appear at the positive, while methyl, in combination with hydrogen, viz., as marsh-gas, would be observed at the negative pole. The decomposition, which actually takes place, is not in perfect accordance with this supposition, as will be seen by the experiments hereinafter described. The results*

obtained, however, are by no means less interesting, and deserve particular attention, opening as they do a prospect that the electrolytical decomposition of organic compounds will afford most important disclosures with reference to their chemical constitution." (See chapter Electro-Chemistry of Proteins.) The discovery of X-rays and the latest findings of J. J. Thomson, Rutherford, and other English physicians, as well as Millikan in this country, have given us ample proof and verification of the theory of Benjamin Franklin that there is but one kind of electricity, the opposite polarities and other dissimilar manifestations of its action being indicative of either an excess or deficiency of charge or potential. A current of electricity is an actual solid flow of electrons in nature's effort to establish equilibrium between an overcharged body and an undercharged body. These discoveries have shown us that matter in its primary form, the atom, is charged with corpuscles of electricity, called electrons, ions, the atoms of the various elements being each composed of a different quantity of electrons in accordance with their own characteristics. The relation of the electron to the atom is supposed to be similar to that of the planets in our solar system to the solar system itself, the electrons being analogous to the planets and the atom to the solar system. This theory is too well known to fully discuss here. It can be fully studied in the recent works of Prof. Millikan. A few points of particular interest to this discussion are:

In solids, electrons may be found momentarily free, unattached to atoms when conducting a current of electric power.

In fluids, electrons are found outside of atoms to a greater extent than in solids, though they are not

numerous if the fluid be composed of pure atoms, such as freshly distilled water. If the water contains a solid in solution (such as all body compounds) an abundance of free electrons are present and it is capable of electrolysis.

In gases such as the air, free electrons are frequently present in abundance outside of the atoms of oxygen, nitrogen, and other constituents. Electrical changes in the air such as static, or high frequency (radio frequency), are capable of changing or breaking up this natural condition of the air as in the formation of ozone, which is a splitting up of oxygen and nitrogen and which has 50 per cent greater density than oxygen. Three volumes of oxygen make up two of ozone.

Light itself is nothing but a flow of free electrons at certain velocities or vibrations according to the spectrum of the light, carrying with it its own magnetic field. Here is where we enter the most interesting phase of this subject. It is proven now that the free electrons of light when absorbed in matter set up feeble electric currents which will excite or move a sensitive galvanometer. Light rays after absorption into substances and subsequent changing of velocity or vibrations radiate out from this substance as infra-red rays, which again can be detected by their manifestation of heat and measured on a bolometer. These infra-red or heat rays are also the most penetrable of any known rays. Ultra-violet rays, as well as X-rays, are the short or high velocity rays of the spectrum. When radiated on chemical compounds they will cause in them direct chemical changes.

Evidently all chemical and physiological phenomena are due to reactions between ions, electrons. Life

itself can only be maintained by their free movements, and that also calls for their free play in the presence of water in the reducing of complex bodies into simple compounds. Different concentrations of ions, or movements of electrons in membranes, or better still in the conductive medium of nerves, result, through the laws of osmosis, in the basic processes underlying growth, nutrition and decay as well as in the production of function.

ELECTRICAL

If we want to understand the way in which electric and magnetic properties depend on the temperature, the density, the chemical constitution, or the crystalline state of substances, we cannot be satisfied with simply introducing for each substance the co-efficients, whose values are to be determined by experiment; we shall be obliged to have recourse to some hypothesis about the mechanism that is at the bottom of the phenomena.

It is by this necessity that one has been led to the conception of electrons, i. e., of extremely small particles, charged with electricity, which are present in immense numbers in all ponderable bodies, and by whose distribution and motions we endeavor to explain all electrical and optical phenomena that are not confined to the free ether. My task will be to treat some of these phenomena in detail, but I may at once say that, according to our modern views, the electrons in a conducting body, or at least a certain part of them, are supposed to be in a free state, so that they can obey an electric force by which the positive particles are driven into one, and the negative electrons in the opposite direction. In the case of a non-conducting

substance, on the contrary, we shall assume that the electrons are bound to certain positions of equilibrium. If, in an electric wire, the electrons of one kind, say the negative ones, are traveling in one direction, and perhaps those of the opposite kind in the opposite direction, we have to do with a current of conduction, such as may lead to a state in which a body connected to one end of the wire has an excess of either positive or negative electrons. This excess, the charge of the body as a whole, will, in a state of equilibrium and if the body consists of a conducting substance, be found in a very thin layer at its surface.

A substance in which the electrons are shifted to new positions is said to be electrically polarized.

Again, under the influence of the elastic forces, the electrons can vibrate about their positions of equilibrium. In doing so, and perhaps on account of other more irregular motions, they become the centers of waves that travel outwards in the surrounding ether and can be observed as light if the frequency is high enough. In this manner we can account for the emission of light and heat. The opposite phenomenon, that of absorption, is explained by considering the vibrations that are communicated to the electrons by the periodic forces existing in an incident beam of light. If the motion of the electrons thus set vibrating does not go on undisturbed, but is converted in one way or another into the *irregular agitation* which we call *heat,* it is clear that part of the incident energy will be stored up in the body, in other terms that there is a certain absorption.

Nor is it the absorption alone that can be accounted for by a communication of motion to the electrons. This optical resonance, as it may in many cases be

termed, can likewise make itself felt if there is no resistance at all, so that the body is perfectly transparent. In this case also, the electrons contained within the molecules will be set in motion, and though *no vibratory* energy is lost, the oscillating particles will exert an influence on the velocity with which the vibrations are propagated through the body. By taking account of this reaction of the electrons, we are enabled to establish an electro-magnetic theory of the refrangibility of light in its relation to the wave-length and the state of the matter, and to form a mental picture of the beautiful and varied phenomena of double refraction and circular polarization. It is indeed remarkable how these early speculations fifteen years later find their verification in actual demonstration and experiment (see Millikan on the Electron), which give final proof to our findings and conclusions on the "first-external-excitor-factor" in Protoplasm.

On the other hand, the theory of the motion of electrons in metallic bodies has been developed to a considerable extent. Though here also much remains to be done, new questions arising as we proceed, we can already mention the important results that have been reached by Riecke, Drude, and J. J. Thomson. The fundamental idea of the modern theory of the thermic and electric properties of metals is, that the free electrons in these bodies partake of the heat-motion of the molecules or ordinary matter, traveling in all directions with such velocity that the mean kinetic energy of each of them is equal to that of a gaseous molecule at the same temperature. If we further suppose the electrons to strike over and over again against metallic atoms, so that they describe irregular zigzag lines, we can make clear to ourselves the reason that metals are

at the same time good conductors of heat and electricity, and that, as a general rule, in the series of the metals, the two conductivities change in nearly the same ratio. The larger the number of free electrons, and the longer the time that elapses between two successive encounters, the greater will be the conductivity for heat as well as that for electricity.

This rapid review will suffice to show that the theory of electrons is to be regarded as an extension to the domain of electricity of the molecular and atomistic theories that have proved these. It is apt to be viewed unfavorably by some physicists, who prefer to push their way into new and untried regions by following those great highways of science which we possess in the laws of thermodynamics, or who arrive at important and beautiful results, simply by describing the phenomena and their mutual relations by means of a system of suitable equations. No one can deny that these methods have a charm of their own, and that, in following them, we have the feeling of treading on firm ground, whereas in the molecular theories, the too adventurous physicist often runs the risk of losing his way and of being deluded by some prospect of success. We must not forget, however, that these molecular hypotheses can boast of some results that could never have been attained by pure thermodynamics, or by means of the equations of the electro-magnetic field in their most general form, results that are well known to all have studied the kinetic theory of gases, the theories of dilute solutions, of electrolysis, and of the genesis of electric currents by the motion of ions. Nor can the fruitfulness of these hypotheses be denied by those who have followed the splendid researches on the conduction of electricity

through gases of J. J. Thomson and his fellow-workers. (Notes from Lorenz, 1908.)

"We can assume that an electro-magnetic field in the ether is never produced by any other causes than the presence and motion of electrons."

"It appears from this that the electron is continually surrounded by the same field, which it may therefore be said to carry along with it."

"Considering the course of the electric and the magnetic lines of forces which interest each other at right angles, we must conclude that there is a current of energy, whose general direction is that of the translation of the electron. This should have been expected, since the moving electron is constantly surrounded by the same field. The energy of this field may be said to accompany the particle in its motion."

"Consequently, the masses of the positive electrons must be comparable with those of chemical atoms. We can therefore imagine the free electrons to be the product of a disintegration (see explanation, Part II of this book, by Prof. Calvin Samuel Page) of atoms, of a division into a positively and a negatively charged particle, the first having nearly the whole mass of the atom, and the second only a very small part of it."

"Of late the question has been discussed, as to whether the idea that there is no material but only electro-magnetic mass, which, in the case of negative electrons, is so strongly supported by Kaufmann's results, may not be extended to positive electrons and to matter in general. On this subject of an electro-magnetic theory of matter, we might observe that if we suppose atoms to contain negative electrons, of which one or more may be given off under certain circum-

stances, as they undoubtedly are, and if the part that remains after the loss of a negative particle is called a positive electron, then certainly all matter may be said to be made up of electrons. But this would be mere words. What we really want to know is, whether the mass of the positive electron can be calculated from the distribution of its charge in the same way that we can determine the mass of a negative particle. This remains, I believe, an open question, about which we shall do well to speak with some reserve."

"In all cases in which the work of the force is negative, the energy of the electron (if not kept at a constant value by the action of some other cause) must diminish, and that of the ether must increase. This means that there is a continuous radiation from the particle outwards, such as cannot be said to exist when the velocity is constant and the electron simply carries its field along with it."

We know that an electron can be the center of an emission of energy only when its velocity changes.

"If a source of light, giving one or more sharp lines in the spectrum, is placed between the poles of a powerful electro-magnet, each line is split into a certain number of components, whose distances are determined by the intensity of the external magnetic force."

"If it is further taken into account that the frequency of the rays is in every case equal to that of the motion originating them, one can draw the following conclusions, which have been fully verified by Zeeman's experiments.

"Let the source of light be placed in a magnetic field whose lines of force are horizontal, and let the light emitted in a horizontal direction at right angles to the lines to force be examined by means of a spectroscope

or a grating. Then we shall see a triplet of lines, whose middle component occupies the place of the original line. Each component is produced by plane polarized light, the electrical vibrations being horizontal for the middle line, and vertical for the two outer ones."

"If however, by using an electro-magnet, one core of which has a suitable axial hole, we examine the light that is radiated along the lines of force, we shall observe only a doublet, corresponding in position to the outer lines of the triplet. Its components are both produced by circularly polarized light, the polarization being righthanded for one and lefthanded for the other."

"This agrees with the general result of other lines of research, but the negative charges have a greater mobility than the positive ones."

"It is clear in what way we can escape from the difficulty I just now pointed out. We must ascribe the radiation, not to the distortional vibrations of electrons, but to vibrations in which they move as a whole over certain small distances. Motions of this kind can exist in an atom which contains a certain number of negative electrons, arranged in such a manner that they are in stable equilibrium under the influence of their mutual forces, and of those that are exerted by the positive charges in the atom. This conception is very like an assumption that has been developed to a considerable extent by J. J. Thomson, The Corpuscular Theory of Matter, London, 1907, and according to which an atom consists of a positive charge uniformly distributed over a spherical space, a certain number of negative electrons being embedded in this sphere, and arranging themselves in a definite geometrical configuration."

"It is easily seen that a number of negative electrons can never form a permanent system, if not held together by some external action. This action is provided for in J. J. Thomson's model by the positive sphere, which attracts all the electrons towards its center O, and which must be supposed to extend beyond the electrons, because otherwise there could be no true statis equilibrium."

"As is well known, the general outcome of the researches on the B-rays of radio-active bodies and on the canal rays has been that the positive electricity is always attached to the mass of an atom. In accordance with this result, we shall consider the positive sphere as having nearly the whole mass of the atom, a mass that is so large in comparison with that of the negative electrons, that the sphere can be regarded as immovable, while the electrons can be displaced within it."

"In the preceding discussion, we had in view the influence of a magnetic field on the light *emitted* by a source of light. There is a corresponding influence on the absorption, as was already shown by one of Zeeman's first experiments. He found that the dark lines which appear in the spectrum of a beam of white light, passed through a sodium flame, are changed in exactly the same way as the emission lines of the luminous vapor, when the flame is exposed to an external magnetic field. We can easily understand this inverse phenomenon if we bear in mind the intimate connection between the emission and the absorption of light. According to the well known law of resonance, a body whose particles can execute free vibrations of certain definite periods must be able to absorb light of the same periods which it received from without. There-

fore, if in a sodium flame under the influence of a magnetic field there are three periods of free vibrations instead of one, we may expect that the flame can produce in a continuous spectrum three absorption lines corresponding to these periods, and in general, if we want to know what kinds of light are emitted by a body under certain circumstances, we have only to examine the absorption in a beam of light sent across it."

"It has occurred to me that this may be found in the assumption that the vibrations in the interior of a ponderable particle that are excited by incident waves of light cannot go on undisturbed forever. It is conceivable that the particles of a gaseous body are so profoundly shaken by their mutual impacts, that any regular vibration which has been set up in them is transformed by the blow into the *disorderly motion which we call heat. The rise in temperature produced in this way must be due to a part of the energy of the incident rays, so that there is a real absorption of light.* It is also clear that the accumulation of vibratory energy in a particle, which otherwise, in the case of an exact agreement between the period of the vibrating electrons and that of the incident light, would never come to an end, will be kept within certain limits by this disturbing influence of the collisions, just as well as it could be by a resistance in the ordinary sense of the word."

"This explanation is very much like that which was proposed by several physicists who developed the undulatory theory of light in its original form in which the ether was considered as an elastic body. Sellmeyer, Ketteler, Boussinesq, and Helmholtz showed that the velocity of light must depend on the period of the vibrations, as soon as a body contains small particles

which are set vibrating by the forces in an incident beam of light, and which are subject to intra-molecular forces of such a kind that they can perform free vibrations of a certain definite period. The amplitude of the forced vibrations of these particles, which is one of the quantities determining the velocity of propagation, will largely depend on the relative lengths of their own period of vibration and the period of light falling on them. The theory of the propagation of light in a system of molecules which has been here set forth is based on the same principles as those older explanations of dispersion, the only difference being that we have constantly expressed ourselves in the terms of the electro-magnetic theory, and that the small particles imagined by Sellmeyer have now become our electrons."

The general meaning of this result will be obvious. When we find that some quantity which determines the refractory of a compound is made up of a number of parts, each of which belongs to one of the elements, we may conclude that, in the propagation of light, *each element exerts an influence of its own, which is not disturbed by the influence of the other elments.* In the terms of our theory, this amounts to saying *that the electric vibrations going on in a beam of light, in so far as they take place in the ponderable matter, have their seat in the separate atoms, the motions in one atom being more or less independent of those in the other atoms of the molecule.*

"We may suppose, for example, that each atom contains one movable electron, which, after a displacement from its position of equilibrium, is pulled back toward it by an elastic force having its origin in the atom itself, and determined, therefore, by the

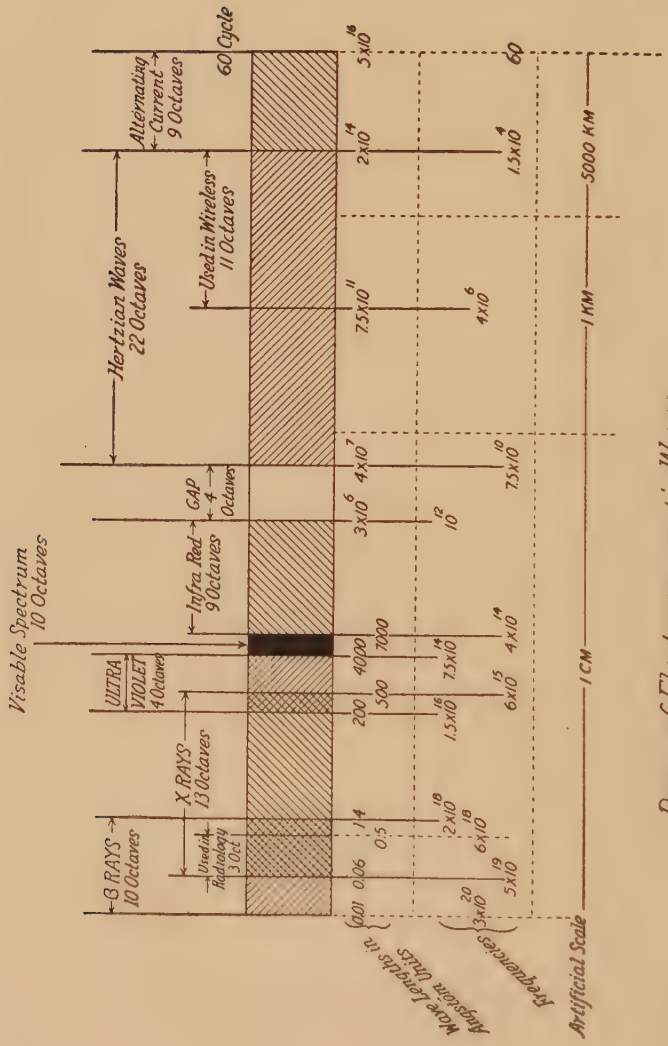
properties of the atom. If we take this view, it is easy so to change the equations for the propagation of light that they can be applied to a system of polyatomic molecules."

It will be most interesting to study Calvin Samuel Page and his beautifully simple, if somewhat radical, explanation of atomic cohesion and electronic repelling, Part II of this book.

"I need hardly observe that the assumption we have made are at best rough approximations to the true state of things. We have supposed the elastic force by which the movable electron of an atom is pulled towards its position of equilibrium to arise from actions which are confined to the atom itself. Now, there is at all events an interaction of an electric nature between neighboring atoms, precisely on account of the displacement of their electrons; there may also be other interactions about whose nature we are as yet entirely in the dark. On these grounds we must expect greater or smaller deviations from the law of the refraction equivalent, deviations from which one may one day be able to draw some conclusions concerning the structure of a molecule."

"One important result in this direction was already obtained by Bruhl. He found that a double chemical binding between two atoms has a striking influence on the refractivity, which can be taken into account, if, in a formula, we add a term of proper magnitude for each double bond."

This remark is important, because it explains the fact that the Roentgen rays do not suffer any refraction when they enter a ponderable body. These rays, though not constituted by regular vibrations, are in all probability produced by a very rapid succession of



Range of Electromagnetic Waves
Over 60 Octaves: Uniform Velocity 3×10^{10} CM per second
(1 Angstrom Unit = 10^{-8} CM)

electro-magnetic disturbances of extremely short duration.

"It appears from these considerations that the idea of a deformability of electrons would give rise to several new problems. One of these would be that of the rotation of these particles. An electron is set spinning whenever a magnetic force to which it is exposed undergoes a change, and it would be necessary to obtain an insight into the peculiarities of the motion imparted in cases of this kind to our flattened ellipsoids."

Oxygen under an electric spark is transformed into ozone, which is 50 per cent greater in density than oxygen. Three volumes of oxygen make up two of ozone.

ROBERT ANDREWS MILLIKAN ON "THE ELECTRON"

In a paper read before the British Association at Belfast in 1874, G. Johnstone Stoney not only stated clearly the atomic theory of electricity, but actually went so far as to estimate the value of the elementary electrical charge, and he obtained a value which was about as reliable as any which had been found until within quite recent years. He got 3×10^{-10} absolute electrostatic units, and he got this result from the amount of electricity necessary to separate from a solution one gram of hydrogen, combined with kinetic theory estimates as to the number of atoms of hydrogen in two grams, i. e., in one gram molecule of that element. This paper was entitled, "On the Physical Units of Nature," and though read in 1874 it was not published in full until 1881. After showing that all physical measurements may be expressed in terms of three fundamental units, he asserts that it would be possible to replace our present purely arbitrary units (the centi-

meter, the gram, and the second) by three natural units, namely, the velocity of light, the co-efficient of gravitation, and the elementary electrical charge. With respect to the last he says:

Finally nature presents us with a single definite quantity of electricity which is independent of the particular bodies acted on. To make this clear, I shall express Faraday's law in the following terms, which, as I shall show, will give it precision, viz.: For each chemical bond which is ruptured within an electrolyte a certain quantity of electricity traverses the electrolyte which is the same in all cases. This definite quantity of electricity I shall call E_1. If we make this our unit of electricity, we shall probably have made a very important step in our study of molecular phenomena.

Hence we have good reason to suppose that in V_1, G_1, and E_2, we have three of a series of systematic units that in an eminent sense are the units of nature, and stand in an intimate relation with the work which goes on in her mighty laboratory.

The latest experimental value of e given by Millikan in his isolation and determination of the electron is as follows:

$e=4.774\times10^{-10}$ absolute electrostatic units.

e in the above equation is the quantity of electricity represented by an electron.

All static charges both on conduction and insulators are built up of electrons.

"The number of electrons contained in the quantity of electricity which courses every second through a common sixteen-candle-power electric-lamp filament, and for which we pay 1/100,000 of 1 cent, is so large that if all the two and one-half million inhabitants of

Chicago were to begin to count out these electrons and were to keep on counting them out each at the rate of two a second, and if none of them were ever to stop to eat, sleep, or die, it would take them just twenty thousand years to finish the task."

The act of ionization by beta-rays seems to consist in the shaking off without any appreciable energy of one single electron from an occasional molecule through which the beta-ray passes. The faster the beta-ray the less frequently does it ionize.

The act of ionization by ether waves, i. e., by X-rays or light, seems to consist in the hurling out, with an energy which may be very large, but which depends upon the frequency of the incident ether wave, of one single electron from an occasional molecule over which this wave passes.

The act of ionization by rapidly moving alpha-particles consists in shaking loose of one single electron from the atom through which it passes, but a slow moving positive ray appears in some cases to be able to detach several electrons from a single atom. (See Gottschalk and Kelly, Phys. Rev. 1917.)

THE STRUCTURE OF THE ATOM

We have shown how within the last two decades there has been discovered beneath the nineteenth-century world of molecules and atoms a wholly new world of electrons, the very existence of which was undreamed of twenty years ago. We have seen that these electrons, since they can be detached by X-rays from all kinds of neutral atoms, must be constituent of all atoms. Whether or not they are the sole constituents we have thus far made no attempt to determine. We have concerned ourselves with studying the prop-

erties of these electrons themselves and have found that they are two kinds, negative and positive, which are, however, exactly alike in strength of charge but wholly different in inertia or mass, the negative being commonly associated with a mass which is but 1/1,845 of that of the lightest known atom, that of hydrogen, while the positive appears never to be associated with a mass smaller than that of the hydrogen atom. We have found how to isolate and measure accurately the electronic charge and have found that this was the key which unlocked the door to many another otherwise inaccessible physical magnitude. It is the purpose here to consider certain other fields of exact knowledge which have been opened up through the measurement of the electron, and in particular to discuss what the physicist, as he has peered with his newly discovered agencies, X-rays, radioactivity, ultra-violet light, etc., into the insides of atoms, has been able to discover regarding the numbers and sizes and relative positions of these electronic constituents, and to show how far he has gone in answering the question as to whether the electrons are the sole building-stones of the atoms.

THE SIZE OF ATOMS

One of the results of the measurement of the electronic charge was to make it possible to find the quantity which is called the diameter of an atom with a definition and precision heretofore altogether unattained.

It is shown herein that the determination of e gave us at once a knowledge of the exact number of molecules in a cubic centimeter of a gas. Before this was known we had fairly satisfactory information as to the

relative diameters of different molecules, for we have known for a hundred years that different gases when at the same temperature and pressure possess the same number of molecules per cubic centimeter (Avogadro's rule). From this it is at once evident that, as the molecules of gases eternally dart hither and thither and ricochet against one another and the walls of the containing vessel, the average distance through which one of them will go between collisions with its neighbors will depend upon how big it is. The larger the diameter the less will be the mean distance between collsions —a quantity which is technically called "the mean free path." Indeed, it is not difficult to see that in different gases the mean free path L is an inverse measure of the molecular cross-section. The exact relation is easily deduced. It is

$$L = \frac{1}{3.146\, n d^2\, (2)^{\frac{1}{2}}} \quad (31)$$

in which d is the molecular diameter and n is the number of molecules per cubic centimeter of the gas. Now, we have long had methods of measuring L for it is upon this that the co-efficient of viscosity of the gas largely depends. When, therefore, we have measured the viscosities of different gases we can compute the corresponding L's and then from equation (31) the relative diameter d, since n is the same for all gases at the same temperature and pressure. But the absolute value of d can be found only after the absolute value of n is known. If we insert in equation (31) the value of n found e by the method presented herein, it is found that the average diameter of the atom of the monatomic gas helium is 2×10^{-8} cm., that of the diatomic hydrogen molecule is a trifle more, while the

diameters of the molecules of the diatomic gases, oxygen and nitrogen, are 50 per cent larger. (Millikan.) This would make the diameter of a single atom of hydrogen a trifle smaller, and that of a single atom of oxygen or nitrogen a trifle larger than that of helium. By the average molecular diameter we mean the average distance to which the center of two molecules approach one another in such impacts as are continually occurring in connection with the motions of thermal agitation of gas molecules—this and nothing more.

As will appear, the reason that two molecules thus rebound from one another when in their motion of thermal agitation their centers of gravity approach to a distance of about 2×10^{-8} cm., is presumably that the atom is a system with negative electrons in its outer regions. When these negative electrons in two different systems which are coming into collision approach to about this distance, the repulsion between these similarly charged bodies begins to be felt, although at a distance the atoms are forceless. With decreasing distance this repulsion increases very rapidly until it becomes so great as to overcome the inertias of the systems and drive them asunder.

No more exact or more consistent multiple relationship is found in the data which chemists have amassed on the combining powers of the elements, and upon which the atomic theory of matter rests than is found in Millikan's work on the Electron.

It is further one of the capital discoveries of the twentieth century (Bucherer, Annalen der Physik) that within these limits the observed rate of variation of the mass of the negative electron with speed agrees accurately with the rate of variation computed on the assumption that this mass is all of electrical origin.

THE NATURE OF RADIANT ENERGY

"The problems thus far discussed have all been in the domain of molecular physics, but the discovery and measurement of the electron have also exerted a powerful influence upon recent developments in the domain of ether physics. These developments are of extraordinary interest and suggestiveness, but they lead into regions in which the physicist sees as yet but dimly—indeed even more dimly than he thought he saw twenty years ago.

But while the beauty of a problem solved excites the admiration and yields a certain sort of satisfaction, it is after all the unsolved problem, the quest of the unknown, the struggle for the unattained, which is of most universal and most thrilling interest. I make no apologies, therefore, for introducing in this chapter one of the great unsolved problems of modern physics, nor for leaving it with but the vaguest of suggestions toward a solution." (Millikan.)

THE CORPUSCULAR AND THE ETHER THEORIES OF RADIATION

"The newest of the problems of physics is at the same time the oldest. For nothing is earlier in the experiences either of the child or of the race than the sensation of receiving light and heat from the sun. But how does light get to us from the sun and the stars through the empty interstellar spaces? The Greeks answered this query simply and very satisfactorily from the standpoint of people who were content with plausible explanations, but had not yet learned perpetually to question nature experimentally as to the validity or invalidity of a conclusion. They said that the sun and all radiators of light and heat must shoot off minute

corpuscles whose impact upon the eye or skin produces the sensations light and warmth. (See Calvin Samuel Page, Part II, this book.) (1) The facts of interference were not only found inexplicable in terms of it, but they were completely predicted by the wave theory. (2) The fact that the speed of propagation of light was experimentally found to be greater in air than in water was in accord with the demands of the ether theory, but directly contrary to the demands of the corpuscular theory. (3) Wireless waves had appeared and had been shown to be just like light waves save for wave-length, and they had been found to pass over continuously, with increasing wave-length, into static electrical fields such as could not possibly be explained from a corpuscular point of view. (4) The speed of light had been shown to be independent of the speed of the source as demanded by the ether theory and denied by the corpuscular theory.

By 1900, then, the ether theory had become apparently impregnably intrenched. A couple of years later it met with some opposition of a rather ill-considered sort, as it seems to me, from a group of extreme advocates of the relativity theory, but this theory is now commonly regarded, I think, as having no bearing whatever upon the question of the existence or non-existence of a luminiferous ether. For such an ether was called into being solely for the sake of furnishing a carrier for electro-magnetic waves, and it obviously stands or falls with the existence of such waves *in vacuo,* and this has never been questioned by anyone so far as I am aware."

(We must admit that here Calvin Samuel Page stands alone, with an explanation that is as simple as it is radical. Whether we accept him or not, we have as yet not been able to disprove him.)

DIFFICULTIES CONFRONTING THE WAVE THEORY

Up to 1903, then, the theory which looked upon an electro-magnetic wave as a disturbance which originated at some point in the ether at which an electric charge was undergoing a change in speed, and was propagated from that point outward as a spherical wave or pulse, the total energy of the disturbance being always spread uniformly over the wave front, had met with no serious question from any source. Indeed, it had been extraordinarily successful, not only in accounting for all the known facts, but in more than one instance in predicting new ones. The first difficulty appeared after the discovery of the electron and in connection with the relations of the electron to the absorption or emission of such electro-magnetic waves. It was first pointed out in 1903 by Sir J. J. Thomson in his Silliman lectures at Yale. It may be stated thus: X-rays unquestionably pass over or pass all but an exceedingly minute fraction, say one in a thousand billion, of the atoms contained in the space traversed without spending any energy upon them or influencing them in any observable way. But here and there they find an atom from which they hurl a negative electron with enormous speed. This is the most interesting and most significant characteristic of X-rays, and one of which distinguishes them from the alpha- and beta-rays just as sharply as does the property of non-deviability in a magnetic field; neither alpha- nor beta-rays ever eject electrons from the atoms through which they pass with speed comparable with those produced by X-rays, else there would be new zigzag lines branching out from points all along the paths of the alpha and beta particles.

But this property of X-rays introduces a serious diffi-

culty in the ether theory. For if the electric intensity in the wave front of the X-ray is sufficient thus to hurl a corpuscle with huge energy from one particular atom, why does it not at least detach corpuscles from all of the atoms over which it passes?

Again, when ultra-violet light falls on a metal it, too, like X-rays, is found to eject negative electrons. This phenomenon of the emission of corpuscles under the influence of light is called the photo-electric effect. Lenard first made the astonishing discovery that the energy of ejection of the corpuscle is altogether independent of the intensity of the light which causes the ejection, no matter whether this intensity is varied by varying the distance of the light or by introducing absorbing screens. I have myself subjected this relation to a very precise test and found it to hold accurately. Furthermore, this sort of independence has also been established for the negative electrons emitted by both X- and Gamma-rays.

Facts of this sort are evidently difficult to account for on any sort of a spreading-wave theory. But it will be seen that they lend themselves to easy interpretation in terms of a corpuscular theory, for if the energy of an escaping electron comes from the absorption of a light corpuscle, then the energy of emission of the ejected electron ought to be independent of the distance of the source, as it is found to be, and furthermore corpuscular rays would hit but a very minute fraction of the atoms contained in the space traversed by them. This would explain, then, both the independence of the energy of emission upon intensity and the smallness of the number of atoms ionized.

In view, however, of the four sets of facts mentioned above, Thomson found it altogether impossible to go

back to the old and exploded form of corpuscular theory for an explanation of the new facts as to the emission of electrons under the influence of ether waves. He accordingly attempted to reconcile these troublesome new facts with the wave theory by assuming a fibrous structure in the ether and picturing all electromagnetic energy as traveling along Faraday lines of force conceived of as actual strings extending through all space.

Although this concept, which we shall call the ether-string theory, is like the corpuscular theory in that the energy, after it leaves the emitting body, remains localized in space, and when absorbed, is absorbed as a whole, yet it is after all essentially an ether theory. For in it the speed of propagation is determined by the properties of the medium and has nothing to do with the nature or condition of the source.

Thus the last three of the fatal objections to a corpuscular theory are not here encountered. As to the first one, no one has yet shown that Thomson's suggestion is reconcilable with the facts of interference, though so far as I know neither has its irreconcilability been as yet absolutely demonstrated.

But interference aside, all is not simple and easy for Thomson's theory. For one encounters serious difficulties when he attempts to visualize the universe as an infinite cobweb whose threads never become tangled or broken however swiftly the electrical charges to which they are attached may be flying about.

EINSTEIN'S QUANTUM THEORY OF RADIATION

Yet the boldness and the difficulties of Thomson's "ether-string" theory did not deter Einstein in 1905 from making it even more radical. In order to con-

nect it up with some results to which Planck of Berlin had been led in studying the facts of black-body radiation, Einstein assumed that the energy emitted by any radiator not only kept together in bunches or quanta as it traveled through space, as Thomson had assumed it to do, but that a given source could emit and absorb radiant energy only in units which are all exactly equal to hu, u being the natural frequency of the emitter and h a constant which is the same for all emitters.

I shall not attempt to present the basis for such an assumption, for, as a matter of fact, it had almost none at the time. But whatever its basis, it enabled Einstein to predict at once that the energy of emission of corpuscles under the influence of light would be governed by the equation

$$\tfrac{1}{2}mv^2 = Ve = hu - p \quad (41)$$

in which hu is the energy absorbed by the electron from the light wave or light quantum, for, according to the assumption, it was the whole energy contained in that quantum, p is the work necessary to get the electron out of the metal, and $\tfrac{1}{2}mv^2$ is the energy with which it leaves the surface—an energy evidently measured by the product of its charge e by the potential difference V against which it is just able to drive itself before being brought to rest.

At the time at which it was made this prediction was as bold as the hypothesis which suggested it, for at that time there were available no experiments whatever for determining anything about how the positive potential V necessary to apply to the illuminated electrade to stop the discharge of negative electrons from it under the influence of monochromatic light varied with the frequency u of the light, or whether the quan-

tity h to which Planck had already assigned a numerical value appeared at all in connection with photo-electric discharge. We are confronted, however, by the astonishing situation that after ten years of work at the Ryerson Laboratory and elsewhere upon the discharge of electrons by light this equation of Einstein's seems to us to predict accurately all of the facts which have been observed.

ATTEMPTS TOWARD A SOLUTION

It is possible, however, to get a certain distance toward a solution and to indicate some conditions which must be satisfied by the solution when it is found. For the energy hu with which the electron is found by experiment to escape from the atom must have come either from the energy stored up inside of the atom or else from the light. There is no third possibility. Now the fact that the energy of emission is the same, whether the body from which it is emitted is held within an inch of the source, where the light is very intense, or a mile away, where it is very weak, would seem to indicate that the light simply pulls a trigger in the atom which itself furnishes all the energy with which the electron escapes, as was originally suggested by Lenard in 1902, or else, if the light furnishes the energy, that light itself must consist of bundles of energy which which keep together as they travel through space, as suggested in the Thomson-Einstein theory.

Yet the fact that the energy of emission is directly proportional to the frequency u of the incident light spoils Lenard's form of trigger theory, since, if the atom furnishes the energy, it ought to make no difference what kind of a wave-length pulls the trigger, while it ought to make a difference what kind of a gun, that

is, what kind of an atom, is shot off. But both of these expectations are the exact opposite of the observed facts. *The energy of the escaping corpuscle must come, then, in some way or other, from the incident light.*

When, however, we attempt to compute on the basis of a spreading-wave theory how much energy a corpuscle can receive from a given source of light, we find it difficult to find anything more than a very minute fraction of the amount which the corpuscle actually acquired.

Thus, the total luminous energy falling per second from a standard candle on a square centimeter at a distance of 3 m. is 1 erg. (Drude, Lehrbuch der optic.) Hence the amount falling per second on a body of the size of an atom, i. e., of cross-section 10^{-15} cm. is 10^{-15} ergs, but the energy *hu* with which a corpuscle is ejected by light of wave-length 500 nn. (millionth millimeter) is 4×10^{-12} ergs, or 4,000 times as much. Since not a third of the incident energy is in wave-lengths shorter than 500 nn., a surface of sodium or lithium which is sensitive up to 500 nn. should require, even if all this energy were in one wave-length, which it is not, at least 12,000 seconds or 4 hours of illumination by a candle 3 m. away before any of its atoms could have received, all told, enough energy to discharge a corpuscle.

Yet the corpuscle is observed to shoot out the instant the light is turned on. It is true that Lord Rayleigh has recently shown that an atom may conceivably absorb wave energy from a region of the order of magnitude of the square of a wave-length of the incident light rather than of the order of its own cross-section. This in no way weakens, however, the

cogency of the type of argument just presented, for it is only necessary to apply the same sort of analysis to the case of gamma-rays, the wave-length of which is of the order of magnitude of an atomic diameter (10^{-8} cm.), and the difficulty is found still more pronounced.

Thus Rutherford estimates that the total gamma-ray energy radiated by one gram of radium cannot possibly be more than 4.7×10^{-4} ergs. Hence at a distance of 100 meters, where the gamma-rays from a gram of radium would be easily detachable, the total gamma-ray energy falling per second on a square millimeter of surface, the area of which is ten thousand billion times greater than that either of an atom or of a disk whose radius is a wave-length, would be $4.7 \times 10^{-4} \div 4 \times 3.1416 \times 10^{-10} = 4 \times 10^{-7}$ ergs.

This is very close to the energy with which beta-rays are actually observed to be ejected by these gamma-rays, the velocity of ejection being about nine-tenths that of light. Although, then, it should take ten thousand billion seconds for the atom to gather in this much energy from the gamma-rays, on the basis of classical theory, the beta-ray is observed to be ejected with this energy as soon as the radium is put in place. This shows that if we are going to abandon the Thomson-Einstein hypothesis of localized energy, which is, of course, competent to satisfy these energy relations, there is no alternative but to assume at some previous time the corpuscle had absorbed and stored up from light of this or other wave-length enough energy so that it needed but a minute addition at the time of the experiment to be able to be ejected from the atom with the energy hu.

Now the corpuscle which is thus ejected by the light

cannot possibly be one of the free corpuscles of the metal, for such a corpuscle, when set in motion within a metal, constitutes an electric current, and we know that such a current at once dissipates its energy into heat. In other words, a *free* corpuscle can have no mechanism for storing up energy and then *jerking* itself up *"by its boot straps"* until it has the huge speed of emission observed.

The ejected corpuscle must then have come *from the inside of the atom,* in which case it is necessary to assume, if the Thomson-Einstein theory is rejected, that within the atom there exists some mechanism which will permit a corpuscle continually to absorb and load itself up with energy of a given frequency until a value at least as large as *hu* is reached. What sort of a mechanism this is, we have at present no idea. (See Calvin Samuel Page, second part of this book.) Further, if the absorption is due to resonance—and we have as yet no other way in which to conceive it—it is difficult to see how there can be, in the atoms of a solid body, corpuscles having all kinds of natural frequencies so that some are always found to absorb and ultimately be ejected by impressed light, of any particular frequency.

But apart from these difficulties, the thing itself is impossible if these absorbing corpuscles, when not exposed to radiation, are emitting any energy at all; for if they did so, they would in time lose all their store and we should be able, by keeping bodies in the dark, to put them into condition in which they should show no emission corpuscles whatever until after hours or years of illumination with a given wave-length. Since this is contrary to experiment, we are forced, even when we discard the Thomson-Einstein theory of localized

energy, to postulate electronic absorbers which, during the process of absorbing, do not radiate at all until the absorbed energy has reached a certain critical value when explosive emission occurs. *The observed characteristics of the effect seem to furnish proof that the emission of energy by an atom is a discontinuous or explosive process.* (See chapter on Synapses.)

This was the fundamental assumption of Planck's so-called quantum theory of radiation. The Thomson-Einstein theory makes both the absorption and the emission sudden or explosive, while the loading theory first suggested by Planck, though from another viewpoint, makes the absorption continuous and only emission explosive.

The h determined above with not more than one-half of 1 per cent of uncertainty is the explosive constant, i. e., it is the unchanging ratio between the energy of emission and the frequency of the incident light. It is a constant the existence of which was first discovered by Planck by an analysis of the facts of black-body radiation, though the physical assumptions underlying Planck's analysis do not seem to be longer tenable. For the American physicists Duane, Hunt, and Hull, have recently shown that the same quantity h appears in connection with the impact of corpuscles against any kind of a target, the observation here being that the highest frequency in the general or white-light X-radiation emitted when corpuscles impinge upon a target is found by dividing the kinetic energy of the impinging corpuscles by h. Since black-body radiation is presumably due to the impact of the *free* corpuscles within a metal upon the atoms, it is probable that the appearance of h in black-body radiation and in general X-radiation is due to the same cause, so that, contrary to

Planck's assumption, there need not be, in either of these cases, any coincidence between natural and impressed periods at all. The *hu* which here appears is not a characteristic of the atom, but merely a property of the ether pulse which is generated by the stopping of a moving electron. Why this ether pulse should be resolvable into a continuous, or white-light spectrum which, however, has the peculiar property of being chopped off sharply at a particular limiting frequency given by $hu=PD\ X\ e$ is thus far a complete mystery. All that we can say is that experiment seems to demand a sufficient modification of the ether-pulse theory of white-light and of general X-radiation to take this experimental fact into account.

On the other hand, the appearance of *h* in connection with the absorption and emission of *monochromatic* light (photo-electric effect and Bohr atom) seem to demand some hitherto unknown type of absorbing and emitting mechanism within the atom. This demand is emphasized by the remarkable absorbing property of matter for X-rays, discovered by Barkla and beautifully exhibited in De Broglie's photographs. It will be seen from these photographs that *the atoms of each particular substance transmit the general X-radiation up to a certain critical frequency and then absorb all radiations of higher frequency than this critical value.* The extraordinary significance of this discovery lies in the fact that it indicates that there is a type of absorption which is not due either to resonance or to free electrons. But these are the only types of absorption which are recognized in the structure of modern optics. We have as yet no way of conceiving of this new type of absorption in terms of a mechanical model.

There is one result, however, which seems to be definitely established by all of this experimental work. Whether the radiation is produced by the stopping of a free electron, as in Duane and Hunt's experiments, and presumably also in black-body experiments, or by the absorption and re-emission of energy by bound electrons, as in photo-electric and spectroscopic work, Planck's h seems to be always tied up in some way with the emission and absorption of energy by the electrons. *h may therefore be considered as one of the properties of the electron.*

The new facts in the field of radiation which have been discovered through the study of the properties of the electrons seem, then, to require in any case a very fundamental revision or extension of classical theories of *absorption* and *emission* of radiant energy. The Thomson-Einstein theory throws the whole burden of accounting for the new facts upon the UNKNOWN NATURE OF THE ETHER and makes radical assumptions about its structure. The loading theory leaves the ether as it was and puts the burden of an explanation upon the unknown conditions and laws which exist inside the atom, and have to do with the nature of the electron. I have already given reasons for discrediting the first type of theory. The second type, though as yet very incomplete, seems to me to be the only possible one, and it has already met with some notable successes, as in the case of the Bohr atom. Yet the theory is at present woefully incomplete and hazy. About all that we can say now is that we seem to be driven by newly discovered relations in the field of radiation either to the Thomson-Einstein semi-corpuscular theory, or else to a theory which is equally subversive of the established order of things in physics. For either one of these

alternatives brings us to a very revolutionary quantum theory of radiation.

To be living in a period which faces such a complete reconstruction of our notions as to the way in which ether waves are absorbed and emitted by matter is an inspiring prospect. The atomic and electronic worlds have revealed themselves with beautiful definiteness and wonderful consistency to the eye of the modern physicist, BUT THEIR RELATION TO THE WORLD OF ETHER WAVES IS STILL TO HIM A PROFOUND MYSTERY for which the coming generation has the incomparable opportunity of finding a solution.

In the view of these somewhat conflicting, yet accepted theories, and other questions not entirely settled and understood by physicists, we thought it advisable and constructive to finish this book with an explanation (Phy. of Page) that seems at once to bridge these doubted cross-paths with a compilation of facts, which, though not yet accepted by physicists, at least cannot be disproved, and which in the field of therapeutics give us a new understanding of things, the magnitude of which can only be estimated as time goes on.

CHAPTER II

ELECTROLYSIS

PHYSICISTS have been able, since the discovery of X-ray and radium, to determine with accuracy the nature of the atom; to ascertain with certainty that it is not the smallest part of matter; and to measure, weigh, and count the electrons that compose it. J. J. Thomson and Rutherford and other English physicists are responsible for the conclusions, and it should be noted that they are not theoretic or hypothetic but are based on actual physical measurements.

After one hundred and fifty years these facts confirm the theory of Benjamin Franklin that there is but one kind of electricity, the dissimilar manifestations of its action, for example, opposite polarities, indicating either an excess or deficiency of charge. *This current electricity is an actual flow of electrons in nature's effort to equalize an overcharged and an undercharged body.*

It is known that in a solid conductor, an electric current is a flow of electrons carrying a cathodic charge. In a liquid electrolyte, the flow of current is also only by cathodic electrons and in one direction, but there is a counter-current of whole atoms each with an electric charge or ion, in both directions. This will be shown below. In gases sufficiently rarified to remove nearly all atmospheric pressure the atoms of gas yield their electron to a current and appear as a cathodic stream, as in the X-ray tube.

Electrons compose all matter and are charged points or corpuscles of cathodic or negative electricity, the

atoms of the various elements being each composed of a definite number of electrons depending upon their "combining weights." Thus the hydrogen atom which is the lightest, is composed of 770 electrons, the mercury atom of 150,000 electrons, and the radium atom of even more. We might say that the relation of the electron to the atom may be compared to the relation of the planets in our solar system to the solar system itself; the electrons being analogous to the planets and the atom to the solar system.

No anodic electrons have ever been found.

In solids, electrons may be found momentarily free, unattached to atoms, when conducting a current of electric power.

In fluids, electrons are found outside atoms to a greater extent than in solids, though they are not numerous if the fluid be composed of pure atoms, such as freshly distilled water. If the water contains a solid in solution that is capable of electrolysis an abundance of free electrons are present. The sea, for instance, is an immense storehouse for free electrons.

In gases, such as the air, free electrons are frequently present in abundance outside the atoms of oxygen, nitrogen, and other constituents, particularly during and after a thunderstorm. The souring of milk at these times is doubtless due to free electrons causing ionic change as they seek "cover" in atoms. They have been found in air near waterfalls.

An atom in its state of electronic equilibrium, with its full complement of electrons, possesses its special qualities as an atom. Phosphorous, for instance, if released from combination at once seizes an atom of oxygen and enters into combination again. If, however, it loses a certain number of electrons, thus attaining a

cathodic charge, it becomes an ion, in which condition it loses some of its atomic qualities temporarily and, if free to move in solution in water, it seeks and reaches the anode of a current traversing the solution, where it gives up its charge and regains all the qualities of an atom. Ions with a deficiency of electrons are known as anions; those with an excess of electrons are cations.

Salts are now regarded as molecules formed by the union of a metal ion and an acid, whether the one or the other of the component ions be simple charged atoms, as in sodium chloride, in which the sodium is a cation, and the chlorin an anion, or complex molecules as cocaine hydrochlorate, in which the complex ion cocaine is a cation and the hydrochloric acid an anion.

All molecules are divisible, therefore, into two ions (if they be capable of electrolysis), whether in simple unions of two atoms or in unions of many atoms joined together by their electronic constitution. It is, in fact, the number of electronic components of each atom or group of atoms forming an ion, that dictates whether it is possessed of a deficiency charge and therefore a cation, or an excess charge of electrons and therefore an anion.

The salt molecule itself exists by reason of these opposite reciprocal charges of its ions, chemical affinity being an older name for ionic affinity; the almost irresistible force that compels oppositely charged ions to join each other and remain joined tightly as long as the molecule is dry.

But a salt is no longer a closely knit union of two ions when it is dissolved in water. As soon as solution occurs the electronic bond weakens and large numbers of the ions become dissolved from their partners, retaining, however, their ionic charges, else in the body,

which is but a salt solution, the phosphorous atom, for instance, freed of its charge, would immediately attack the oxygen of the tissues with destructive effect. The presence of the electrolyte in the water serves to dissociate some of the *H O* molecules. Ordinary water contains free ions at all times therefore, due to the impurities dissolved in it from the earth, air, etc., held in solution and themselves partly dissociated.

All chemical and physiologic phenomena are due to reactions between ions. Life itself can only be maintained by their free movements, and death also calls for their free play in the presence of water in reducing complex bodies into simpler compounds. Definite concentrations of ions on either side of membranes result, through the law of osmosis, in the basic processes underlying growth, nutrition and decay, as well as in the production of function.

An electric current driven through a water solution is conducted only by the ions contained in the solution. The amount of current of a given voltage sent through the solution will depend on the degree of the dissociation of the molecules of the dissolved substance and of the water itself into ions, and the valency, or number of electrons, carried by each ion. Plurivalent ions carry electric charges proportional to the large number of electrons they consist of. Complex ions, such as those of the organic compounds, carry charges also proportional to their total constituent electrons. The dissociation of a complex molecule into ions does not mean its decomposition into its ultimate atoms. The cocaine ion in cocaine sulphate or muriate, for instance, is not decomposed into the atoms of which it is composed either by ionic dissociation in water or electrolytic phoresis but merely detached from the acid ion as a

cocaine ion. This is true under the anode and in all parts of the circuit until it reaches the cathode (which never happens in cocaine ionization or cocaine phoresis) where true decomposition doubtless occurs. What, then, happens when we pass a direct current through such a solution of common salt?

On inserting the wires of a d. c. apparatus to opposite ends of the glass or other non-conducting receptacle containing the salt solution and turning on enough power to get readily visible effects, say 50 milliamperes, there will be an instantaneous readjustment of the whole contents of the solution, the free ions will seize partners of opposite charge, even undissociated partners of other charge, and temporarily dissociating them, will whirl around, lose them to other partners back of them of the same sign, and then whirl back for more partners, on their way to the pole they seek—the sodium cations finally reaching the cathode after many exchanges of partners and the chlorin anions the anode. On reaching the cathode wire the sodium and hydrogen cations lose their charges and become atoms in a state that was formerly called "nascent" or new born, attacking surrounding substances with special vigor, which is not great for these atoms. The chlorin and oxygen ions on reaching the wire anode likewise give up their charges, and in their nascent condition attack surrounding substances and even the wire itself with a vigor proportional to their great chemical activities.

There has been doubt among electro-therapeutists as to the possibility of remedial action in this middle region between the poles, but the fact that equal ionic interchanges occur in all parts of the circuit, being only spread out and weakened when the conductor is wide, means that ionic passage through the membrane of cells

and other structures occurs at all points in accord with the concentration of the lines of flow, necessarily involving an alteration of physiologic processes, even though these are slight with the current power usually employed. The results must be due to the forced and artificial flow of ions from structure to structure, for with the brief duration of these applications no external ions could reach the deeper parts, the ionic changes in this situation being those of the body fluids near by, the semi-dissociated conditions being probably the constant state of the molecule of body fluids, the molecules being completely dissociated into ions and reassociated perpetually during life in the chemical changes of anabolism and catabolism.

We have seen that the ions in an electrolyte through which a direct current is passing seek the poles after which they are named carrying an electric charge which suspends their atomic activities, and they give up their charges on reaching the poles and revert to their nascent condition. The necessary result, of course, is a region of chemical activity, at each pole determined by the nature of the atoms freed there, and that the chemical activities at each pole will be in marked contrast to each other.

To recapitulate: The cathode, or so-called negative pole in electrolysis, produces an alkaline, soft water lesion with evidence of caustic soda action, but no hemostatic effects. On a larger scale than depicted in the experiment, especially on hemorrhagic mucous surfaces, it favors hemorrhage and may aggravate such a tendency. It causes hyperemia and thereby quickens local nutrition.

The anode, or positive pole, in electrolysis (with unattackable electrodes) produces a hard, dry acid lesion,

and it is distinctly hemostatic, but not quite as hemostatic as when zinc or zinc and mercury ions are employed. Its immediate action is chemic and sedative.

In medicine and surgery the word "ionization" is now applied in a specific sense, and refers to the driving of foreign ions into the body.

It should first be understood that foreign ions of some kind are always driven into the body whenever a direct or galvanic current traverses it, since conduction in liquids is traveling ions only. When we think we are using plain water on the electrode pads we are really driving in at the anode the base cations of the dissolved substances in the water that render it a conductor, and the acid anions at the cathode.

Alternating currents of all kinds are similarly conducted through the body by the body ions, but the flow of the ions in either direction is for an exceedingly brief moment, and is immediately negatived by a similar flow back to the point of departure. No lasting ionization can therefore be obtained with alternating currents. In the static currents we have true undirectional flows and they are, therefore, theoretically capable of ionization, but their amperage is so insignificant that no material ionic diffusion is possible with them.

The fact that these foreign ions are most intimately diffused into the substance of the smallest anatomical elements, the tissue cells themselves, is a most important fact in contrast to grosser local diffusions of dissolved substances by hypodermic injection, when only intercellular diffusion is possible. In other words, ionization produces intracellular diffusion at once, while mechanical insertion of ions into the tissues can only

be intercellular at first, becoming intracellular only by the aid of subsequent osmotic interchanges.

The difference between this direct local medication of the cells of a part by ionization and the flooding of the body by the ions via the alimentary in order that the local part may reach a similar concentration, is eloquently emphasized by Leduc.

When a foreign ion is diffused into the tissues it does not need to reach the opposite pole on the other side of the body to give its charge and be reduced to its atomic or molecular activities. It is reduced by the opposite ion as soon as it encounters it in the tissues or body fluids, though doubtless the actual ions themselves proceed onward in the circuit toward the opposite pole by a continual union-and-release action with opposite ions encountered moving in the reverse direction, the effect being the outward production along the lines of current flow of new molecules that retain their place more or less, though being made up from moment to moment of ever changing ionic constituents.

Since the foreign ion is thus "reduced" by union with an opposite ion of the tissue substance or fluid as soon as diffused into part, it follows that we obtain a local action in a part, not of a free ion, but of a chemical substance and that the effect must vary and be dependent on the action of the chemical thus created where we want it to be, with actions as varied as the chemicals themselves.

CHAPTER III

X-RAY

WE know that the X-rays are another manifestation of radiant energy, *of which light and heat are familiar examples.* Indeed, the X-rays resemble light rays in almost every particular, the chief difference being that the X-rays have wave-lengths, which are much shorter. In other words, the X-rays are situated away beyond the violent end of the visible spectrum, and may be regarded, in a sense, as a very "treble" form of ultra-violet light. It was this minuteness of wave-length—a distance of the same order as the sizes of atoms—that defeated all our earlier attempts to direct and sort out the rays. All our highest quality polished surfaces are inconceivably rough for such a purpose, and it was not until nature herself was found to have provided an instrument of the requisite delicacy—in the shape of crystals which can function as defraction gratings—that we began to analyze and sort out the X-ray beams with much the same ease as in the case of visible light.

There are further parallelisms between X-rays and light rays. For example, we know that the spectrum of a hot body consists under suitable conditions of white light (which is a mixture of all wave-lengths) superimposed on which are certain spectrum lines whose wave-lengths are characteristic of the radiating material, e. g., the *D* line of sodium and *H* and *K* lines of calcium. In just the same way an element when caused to emit X-rays not only gives out general radiation (which yields a continuous spectrum of wave-lengths) but

under suitable conditions impresses its own characteristic lines on the general spectrum. The characteristic X-ray spectra are found to be much less complicated than light spectra, and are more readily sorted out into groups of series of associated lines.

Experiment has shown the most intimate relationship between X-rays and the electron—either is the manifestation of the other. Whenever an electron has its speed altered, an electro-magnetic wave is produced. If the alteration of the speed of the electron is very great, the frequency of the wave is very high, and we get a high-frequency or "hard" X-ray. If the change of speed is less, the frequency is less and we get a "softer" or less penetrating ray. With much slower electrons, light rays may be similarly produced. Always, however, we find that the frequency of the wave is proportional to the energy given up by the spectrum. There will be a proportion of encounters where the whole of the energy is transferred, and in these cases the frequency will reach an upper limit. Below this limit we find a variety of energy-contents depending on the experience of the electrons involved.

The reverse effect is equally true. *If X-rays or light rays strike a substance they may give all their energy to moving electrons,* or they *may give up only a part;* the rest being transformed to a *series of groups of ray,* all *characteristic of the atom of the material.* The energy balance sheet can be fully written down, and the several items are all definite and specific. The relation is not quite so simple as the general case, but the exchange and partition of energy are equally precise.

The process we have just described is of universal application in nature. There is, for example, little doubt that the X-rays play a prominent part in atmos-

pheric electricity. The earth is not an electrically neutral body, but its surface may be covered with a layer of negative electricity, and this gives rise to an electrical field in the atmosphere. The rate of alteration of potential is found to decrease with the altitude; the potential gradient being about 150 volts per meter on the ground, and only about 2 volts per meter at a height of 9 kilometers—as we know by balloon tests. In other words, the atmospheric conductivity steadily increases the higher we go, and the rapidity of the increase suggests very large values at greater heights.

Some of this conductivity, we know, is due to radioactive emanations from the soil, but we are led to infer from the increase of conductivity with height that the majority is due to some agent *external to our globe.* Modern opinion favors the view that the effect is produced by very *high speed electrons ejected from the sun,* and probably moving nearly as fast as light itself. Some of these strike the atoms of the outer atmosphere, very penetrating X-rays are generated, and thus the whole depth of the atmosphere may be permeated by these electrons through the intermediary of the more penetrating X-rays. It follows that the earth's negative charge which is being continually dissipated by the action of the potential gradient in the atmosphere is steadily replenished by a current of electrons passing downward. It may be added that the conductivity of the air diminishes at night and during a solar eclipse. (See Calvin Samuel Page.)

One is tempted also to believe that in view of the temperature and gigantic electrical disturbances in the sun—as Hale's work has shown and Eddington's speculations would indicate—there may be an emission of X-rays from the sun itself. The sun may be, in fact,

looked upon as a huge X-ray bulb which is responsible directly or indirectly for the part X-rays play in atmospheric electricity, and for the existence of the conducting "Heaviside" layer in the upper atmosphere, which is the main transmitting medium in wireless or radio-telegraphy.

One other source of X-rays in nature may be referred to—the beta radiation of the radio-active elements. It will suffice to say that while some of the beta-rays can be exactly imitated, others are much more penetrating than the X-rays which we have been able to generate artificially.

PRODUCING X-RAYS IN THE CROOKS TUBE

By the use of a focusing device the electrons are concentrated on a small central area of the target, which area is the source of "focus" whence the X-rays set out. Almost all the energy of the electrons is degraded into heat, and for this reason it is essential that the target shall be of a very refractory metal. The great heat developed is removed by water-cooling, radiator fins, or the like. All that we need to consider for the moment is that X-rays radiate uniformly in all directions from the focus, traveling in straight lines just as light rays radiate from a lamp. The X-ray bulb is, indeed, an X-ray lamp, in which the voltage applied to the bulb corresponds to the temperature of a luminous lamp. If we raise the temperature of the latter we increase the intensity and at the same time shorten the average wave-length; so with the X-ray bulb, if we raise the voltage we shorten the average wave-length.

Although X-rays are not in the visible spectrum, they can be detected photographically, or by their power of

exciting fluorescence in screens made of salts, such as barium platinocyanide or cadium tungstate. Another method makes use of the ionizing ability of the rays, and measures the temporary conductivity so produced in a gas. Certain chemical reactions are also induced by the rays, and can be made to serve as the basis of a method of detection and measurement.

Mention may here be made of the necessity of protecting the X-ray operator from the rays. As many of the early workers discovered to their cost, indiscriminate exposure results in dermatitis, which may be followed by dangerous cancerous growths. A further danger is impoverishment of the blood corpuscles.

Various chemical reactions have been brought about by the X-rays such as the discoloring of various alkaline salts (Holzknecht, 1902), and the change of color of pastilles of compressed barium platinocyanide. X-rays resemble light in their property of lowering the electrical resistance of selenium.

The corpuscles of the blood are prejudicially affected by X-rays, resulting in a form of aplastic anaemia. Curiously enough, the rays seem to have little or no action on bacteria or their spores, and in this respect stand out in marked contrast to ultra-violet light.

Two things may happen to a beam of X-ray when passing through a material. Part of it may be absorbed, which means that it is wholly transformed into characteristic radiations of the material, the process always being accompanied by the liberation of electrons. The rest of the beam may be scattered or dispersed, which, in effect, is equivalent to stating that while the rays are unaltered in quality a considerable proportion of them have their direction altered. (References from G. W. C. Kaye.)

CHAPTER IV

ELECTRO-CHEMISTRY OF PROTEINS

WE cannot interpret the chemical action of proteins by comparing their actions to those of the metals or simpler organic compounds, or by means of a study of ordinary chemistry.

The physico-chemical actions of the proteins are here interpreted in conformity with the laws of Boyle and Gay-Lussac, as van't Hoff has applied them to solutions; also in conformity with the Guldberg and Waage mass law which is a direct result of Avogadro's rule and Boyle's law.

The first and second laws of heat have also been assumed applicable in protein systems.

In regard to the electro-chemical actions of the proteins Arrhenius' hypothesis of electrolytic dissociation, Kolrausch's law of the independent motion of ions, the Nernst theory of concentration-cells, and finally, the Guldberg and Waage mass law to reaction between ions, have been applied.

Those proteins that will hardly diffuse and will, with difficulty, crystalize may be broken down into substances which will diffuse and will crystalize by a number of agencies of which hydrolysis and oxidation are the most important.

Linder and Picton found that the precipitating powers of the different salts of a given metal are proportional to their equivalent conductivities, and that the relative precipitating powers of the sulphate of univalent, divalent, and trivalent metals can be expressed by the ratio of 1 to 35 to 1023.

The above ratios have been developed theoretically by Whitham; the theoretical value obtained being reasonably close to the experimental values.

The colloids in each of the cases cited were electronegative for on electrolysis they were attracted to the positive pole.

Hardy demonstrated that by a heating process the partly coagulated protein of a solution of egg albumin could be induced to travel to either the negative or positive pole by changing the solution either to + acid or — alkali respectively.

(The chapter on Electrolysis and Electrons may here be referred to for further information on this subject.)

Temperature influence upon the velocity of protein hydrolysis has been studied by different scientists.

Madsen and Walbaum studied its influence upon the hydrolysis of gelatin by trypsin and found the results to agree with the formula:

$$\frac{V_1}{V_0} = e^{\frac{c}{2}\,\frac{T_1 - T_0}{T_1 \quad T_0}}$$

In the above e is the base of the Napierian logarithms. V_1 and V_0 are the velocities corresponding to absolute temperatures T^1 *and* T_0; c is a constant which is in this case 10,570.

The influence of temperature upon the rate of digestion of thermolgelatin by pepsin may also be found by means of the above formula. In this case we would let c equal 10,750.

The article taken from the appendix to Hardy's article on globulin, which may be found under the atomic structure of cells, affords an explanation to an exceed-

ingly puzzling fact, that is to the individuality of the tissues and tissue-fluids.

For despite the fact that the individual proteins that are found in the tissue-fluid of tolerably nearly related animals appear to be the same upon analysis, the casein of human milk being chemically the same as the casein of cows' and goats' milk, the fibrin of ox-blood appearing to be identical with that of horse-blood, and the serum albumins and globulins of goose-blood being identical with those of horse-blood; the tissue-fluids of one mammal when injected into the circulation of another are treated as foreign intrusions, and give rise to "antibodies"; while the individual protein constituents of these fluids are also treated as foreign matter when introduced into the circulation, giving rise to "precipitation" and to phenomena such as "anaphylaxis."

In consideration of the above and of Hardy's article it may seem that not only the constitution of the individual components of the protein complex is of importance in determining its characteristics but also the relative proportion of these components. Thus two protein complexes of this type might be built up out of individual units, yet differ fundamentally, owing to differences in the combining proportions of these units. It must be understood, of course, that any one constituent of the complex would be totally different from the complex, and thus its injection into the tissues or tissue-fluids would result in disruption of the equilibrium, the disruption having a distinctive character depending upon the kind of tissue or tissue-fluid into which it is injected.

Gay and Robertson and C. L. A. Schmidt have investigated the antigenic properties of several compound

proteins in pursuance of the above idea. Unfortunately, however, a difficulty prevents the scientist from clearly recognizing the presence of antibodies that are specific for the compound protein. The reason for this difficulty is the fact that any protein which is capable of being split by hydrolysis into moieties which are still proteins gives rise, upon introduction into mammals, to antibodies, not only for itself but also for the split-products. Also a compound protein gives rise to antibodies for its constituents, and it is only possible to distinguish between these, which would appear in the blood of immunized animals after injection of the separate constituents, and any antibodies which may be formed for the compound as a whole, in those exceptional cases when the antibody for the compound reacts with a constituent which is not normally antigenic.

The best known compound of proteins with oxygen is that of oxygen with hæmoglobin, the coloring matter of the blood. Hufner studied this, employing the spectrophotometric method of measurement, and found that at high pressure the amount of oxygen bound up by one gram of hæmoglobin is 1,338 c.c., reduced to standard temperature and pressure. Carbon monoxide combines with hæmoglobin in the same proportions.

Hufner considered that the reaction between hæmoglobin and oxygen is a balance reaction, and expressed it by an equation which is reversible.

Bancroft has effectually demonstrated two things in his investigations; in the first place, that the union between hæmoglobin and oxygen is not an "absorption combination"; and in the second place, that hæmoglobin, although a colloid, does not form a separate phase within its solution, but is molecularly distributed

throughout the solution in accordance with the law of Avogadro.

It is a well known fact that living tissues possess the power of "selecting" or storing up certain inorganic constituents in a concentration greater than that in which these substances are found in the surrounding liquid medium. Thus in fresh water streams the proportion of potassium salts is often very low while the proportion of potassium salts in the plants living in these streams is comparatively high.

Whereas, if we place within a dialyser a solution containing an excess of diffusible potassium salts over diffusible sodium salts and dialyse against a solution containing an excess of diffusible sodium salts over diffusible potassium salts, the proportion of salts in the respective solutions will approach an equality.

The above phenomena may be explained by the fact that the inorganic substances that are found in the tissue in excess of their concentration in the fluid surrounding it must exist within the tissue in the form of non-dissociated non-diffusible compounds.

Bugarszky and Lieberman have employed the potentiometric method for the purpose of demonstrating that proteins possess a true combining capacity for acids and bases. This method has also been utilized in determining the relationship of the combining capacity of the protein to the alkalinity or acidity as well as the absolute concentration of their solution.

Hoeber, Farkas, Frænkal, Szily, Hasselbalch, and de Corral have shown by means of the potentiometric method that normal blood is very nearly neutral, the alkalinity first found by Hoeber having been traced to the fact that the stream of hydrogen, used to impregnate the platinum electrode of the gas-chain, washed

the carbon dioxide out of the blood. When this source of error is eliminated the blood is found to be almost absolutely neutral.

Freudenthal and von Szily, employing a somewhat different method of investigation, have reached the above conclusion also.

Moreover, Freudenthal and Foa have shown that not only is the blood very nearly neutral, but with few exceptions the tissue-fluids are practically neutral in reaction. It may be well to state here that Freudenthal and Loeb have proven that the naturally occurring waters in which aquatic animals are found are also very nearly neutral in reaction.

The conclusion may, therefore, be drawn that life-phenomena occur in a nearly neutral liquid, except in certain special localities, such as the internal wall of the stomach. Thus even an increase of 50 per cent in the minute H^+ concentration of normal blood induces profound toxic symptoms, and an increase to $1x10^{-7}$ NH^+ induces fatal acidosis.

Since the products of metabolism include a large proportion of acid substances, it would seem that the mechanism which preserves the neutrality of the tissues and tissue-fluids despite the relatively large daily and hourly fluctuations in acid production or consumption which necessarily occurs within the body is one of prime physiological importance.

UP TO THE PRESENT PURE CHEMISTRY HAS NOT BEEN ABLE TO ACCOUNT FOR THIS NEUTRALIZATION OF ACID PRODUCTION, AND WE MUST LOOK, THEREFORE, FOR THE SOLUTION OF THIS MOST VITAL PROBLEM TO THE ACTION OF ELECTRO-CHEMISTRY; AND WE FIND INDEED THAT THE INFLUENCE OF ELECTRIC OR ELECTRONIC ENERGY (IN THE FULL SENSE OF THAT TERM) CAN ACCOMPLISH

SUCH NEUTRALIZATION, GIVEN THE PROPER ENVIRONMENT.

It has been found that the conductivity of a solution of protein salt has been changed by altering the ratio of salt to water in the solution.

It has also been found that altering the proportion of protein to base or acid in the solution will change its conductivity.

And also it is an important known fact that a change in the temperature will alter the conductivity as well as the chemical integrity of each solution.

Bovie has shown that protein solutions in quartz vessels are coagulated by exposure to ultra-violet light. This type of coagulation consists of two separate processes. The first, namely, that of denaturation, has a very low temperature co-efficient, and takes place almost as rapidly as 0° C. as at room temperature. The second process, namely, that of agglutination or floculation, has a high temperature co-efficient.

However, the action of ultra-violet light is more thoroughly treated under the chapter on cells.

C. J. Martin and W. M. Bayliss have found that the osmotic pressure of hæmoglobin and egg-albumin solutions vary directly with the absolute temperature, thus obeying Gay-Lussac's law.

It is evident that under certain conditions proteins, particularly in the form of their salts, diffuse in water and exert a definite osmotic pressure, although the time required for the protein molecules to distribute themselves uniformly throughout any given volume of fluid may, in certain cases, be very great.

However, apart from direct observation, the fact that proteins and certain other colloids in solution possess a definite osmotic pressure may be deduced from

the fact that chemical reactions which involve them attain definite equilibria.

We may, therefore, conclude that proteins in solution are distributed according to the law of Avogadro. For since, according to the laws of osmosis, the osmotic pressure exercised by a certain quantity of a substance in dilute solution is identical in value with the gaseous pressure, which the same quantity of the same substance would exercise if it were contained as a gas in the same volume at the same temperature, and, since, according to Avogadro's law, equal volumes of gases under the same conditions and temperature and pressure contain equal numbers of molecules, we may conclude that under constant pressure and temperature, two solutions exerting the same osmotic pressure, and having equal volumes of solvent, contain equal numbers of molecules.

It has been found that all proteins having the iron-containing radical, hæmatin, and its derivative, hæmin, are strongly magnetic bodies.

The absorption-spectra of solutions of hæmoglobin and its colored derivatives have been extensively studied.

Gamgee, Soret, Kober, and Harris and Hoyt have studied the spectrum and have arrived at varying conclusions. However, it appears possible that the markedly toxic action of ultra-violet light upon many unicellular organisms may be dependent upon the absorption of the ultra-violet light rays, by the proteins of the organism affected.

Experiments conducted by Euler, Abderhelden and Gigon, Cæmmerer, and Pincussohn have shown that the rate of hydrolysis is effected by the chemical composition of the solution in which it takes place as well as by the temperature.

The effect of high temperatures accelerates the autohydrolysis of proteins and renders more easily detectable a reaction which occurs slowly at all temperatures. For it is possible to demonstrate directly, and without appeal to inference, that the hydrolysis of proteins in neutral watery solutions, does occur at normal temperatures. The observed hydrolysis, therefore, must not be regarded as due to catalysors, but to the action of the solvent water itself or of its ions.

We know that when a catalysor is used in a chemical reaction the catalysor is not perceptibly altered. But if the catalysor is unaltered at the end of the reaction that it accelerates, it must have accomplished this acceleration without adding any energy to or subtracting any energy from the reacting system. Moreover, if the station of equilibrium in any reaction is unaffected by the presence of a given catalysor, then that catalysor must accelerate equally the attainment of equilibrium from either side.

Due to the fact that small quantities of proteolytic enzyme will in certain instances suffice to convert large quantities of protein, it has been urged by many observers that the fermentative splitting of proteins is an instance of typical catalysis. This view has not been justified for it has not been shown that the enzyme remains unaltered in efficiency at the end of extensive hydrolysis.

It is believed by Loeb that the portion of pepsin, which is ionized, is the portion that is active in bringing about the hydrolysis of proteins, and that the active mass of the ferment is increased by acids since they form ionized salts with it.

The edema of the cells characteristic of increased acidity of cytoplasm may be regarded as an adaptation

since it tends to dilution and consequent reduction in the hydrogen-ion concentration. The protein constituents of the cell, none of which can be spared without injury in the case of brain cell, have the power of combining with acids and neutralizing them.

In the digestion of proteins amino-acids are set free. By means of these the acids are in part neutralized as by ammonia, by the formation of salts. In addition, by means of the carboxyl-splitting enzymes, or carboxylases, the carboxyl group is split off, and there remains a base which has much greater power of combining than the amino-acids themselves. This process pertains to all the cells of the organism, with the exception of the brain cell.

Inorganic safeguards against acidosis are the carbonates and phosphates of the blood, which act as buffers. By means of these the blood is able to take up considerable amounts of acid with but slight change in its own acidity.

CHAPTER V

CELLS

THE elements found in the body are carbon, nitrogen, hydrogen, oxygen, sulphur, phosphorous, fluorine, chlorine, iodine, silicon, sodium, potassium, calcium, magnesium, lithium, iron, and occasionally traces of manganese, copper and lead. Of these, very few occur in the free state. Oxygen (to a small extent) and nitrogen are found dissolved in the blood; hydrogen is formed by putrefaction in the alimentary canal. With some few exceptions such as these, the elements enumerated above are found combined with one another to form compounds.

An animal cell is usually of microscopic dimensions, in the human body varying from 1/33 to 1/3000 of an inch in diameter.

It consists of:

1. *Protoplasm.* This makes up the main substance of the cell.

2. *Nucleus.* A vesicular body within the protoplasm, generally situated near the center of the cell.

3. *Centrosome and attraction sphere.* These are contained within the protoplasm, near the nucleus.

The chemical structure of protoplasm when investigated after death yields:

1. *Water.* At least three-quarters of the weight, often more, consists of water.

2. *Proteins.* These are the most constant and abundant of the solids. A protein or albuminous substance consists of carbon, hydrogen, nitrogen, oxygen, with sulphur and phosphorous in small quantities only. In nuclein, a complex material found in the nuclei of

cells, phosphorous is more abundant. The protein obtained in greatest abundance in the cell protoplasm is called a *nucleo-protein;* that is to say, it is a compound containing varying amounts of this material nuclein with protein.

3. *Lipoids.* These are so called because they resemble fats in their solubilities; they are present usually only in small quantities, and those which most constantly occur are phosphorized fats (such as *lecithin*) and *cholesterin,* a monatomic alcohol.

4. *Inorganic Salts.* Especially phosphates and chlorides of calcium, sodium and potassium.

THE NUCLEUS

The chemical composition of the nucleus is found to consist principally of protein and protein-like substances. The nuclei of the cells may be obtained by subjecting the cells to the action of artificial gastric juice; the protoplasm is nearly entirely dissolved, but the nuclei resists the solvent action of the juice. No doubt the nuclei contain *several chemical compounds,* but the only one of which we have any accurate knowledge has been termed *nuclein,* and this is identical with the substance called *chromatin* by histologists. It is soluble in alkalis, but precipitated by acids; it is *different from a simple protein,* as it contains in addition to carbon, nitrogen, oxygen, hydrogen and sulphur in a large quantity (7 to 8 per cent, or even more) of phosphorous in its molecule. In many cases nuclein contains iron also. (See chapter on Electro-Chemistry.)

THE ATTRACTION SPHERE

In addition to the nucleus and protoplasm, most, if not all, living cells contain another structure; it consists

of a minute particle called a *"centrosome,"* which has an attractive influence on protoplasmic fibrils and granules in its neighborhood, the whole appearance produced being called an *attraction sphere.*

It is most prominent in cells which are dividing, or about to divide. The centrosome, and then the attraction sphere become double. In all probability the centrosome gives the primary impulse to cell division. Some cells, for instance, the giant cells of red marrow, contain numerous centrosomes.

PROTOPLASMIC MOVEMENT

The cell by reason of its differentiation of substance as held in distinct atomic composition in protoplasm and nucleus, forms an electro-positive and negative unit. Investigations have shown that although the movements of amœboid cells are commonly described as spontaneous, yet they are produced and increased under the action of external agencies which excite them, and which are therefore called *stimuli,* and if the movement has ceased for the time, as is the case *if the temperature is lowered beyond a certain point,* movement may be *set up by raising the temperature.* Again, contact with foreign bodies, gentle pressure, certain salts, and electric current produce or increase the movement in the amœba. The protoplasm is, therefore, sensitive or irritable to stimuli, and shows its irritability by movement or contraction of its mass. The effect of some of these stimuli may be thus further detailed:

1. *Changes of temperature.* Moderate heat acts as a stimulant; the movement stops when the temperature is lowered near the freezing point, or raised above 40° C. (104° F.); between these two points the movements increase in activity; the optimum temperature

is about 37° to 38° C. Though cold stops the movement of protoplasm, exposure to a temperature even below 0° C. does not prevent its reappearance if the temperature is raised; on the other hand prolonged exposure to a temperature of 42° to 45° C. altogether kills the protoplasm and causes it to enter into a condition of *heat rigor*. This is due to the coagulation of the proteins present.

2. *Chemical stimuli.* Distilled water first stimulates then stops amœboid movement, for by imbibition it causes great swelling and finally bursting of the cells. In some cases, however, (myxomycetes) protoplasm can be almost entirely dried up, but remains capable of renewing its movement when again moistened. Dilute salt solution and very dilute alkalis stimulate the movement temporarily. Acids or strong alkalis permanently stop the movements: ether, chloroform, veratrine and quinine also stop it for a time.

Movement is suspended in an atmosphere of hydrogen or carbonic acid, and resumed on the admission of air or oxygen; complete withdrawal of oxygen will after a time kill protoplasm.

3. *Electrical.* Weak currents stimulate the movement, while strong currents cause the cells to assume spherical form, and to become motionless. (See Electro-Chemistry of Proteins.)

There is no doubt that protoplasmic movement is essentially the same thing in both animal and vegetable cells. But in vegetable cells the cell wall obliges the movement to occur in the interior, while in the naked animal cells the movement results in an external change of form.

After a close perusal of the chapters on Electrons, Electrolysis and Electro-Chemistry of Proteins it must

be clear that all protoplasmic movements are the result of atomic and molecular difference in their structures, which, when subjected to favorable electro-magnetic conditions, having an excess of electrons in motion (heat-light, the whole spectrum, magnetic stresses, gravity, liquids, atmospheric changes), enable these electrons or fundamental particles of electricity (see chapter on Electrons) to seek their own level of potential, as determined by the atomic composition of the molecule, and the electro-magnetic condition of its environment.

THIS THEN RESULTS IN AN ELECTRO-CHEMICAL ACTION, WITH DIFFERENT MANIFESTATIONS. THIS IS WHAT POSSESSES THE CELL WITH THE POWER OF BREATHING, THAT IS, TAKING IN OXYGEN. EVERY OTHER ACTION, NUTRITION, EXCRETION, DIVISION, GROWTH, CAN NOW BE PLAINLY ASCRIBED TO ELECTRO-CHEMICAL ACTION. THIS IN TURN POSSESSES THE CELL WITH ITS ABILITY TO SET UP ITS OWN ELECTRO-MOTIVE FORCE, SO THAT IT MAY GIVE UP A FEEBLE ELECTRIC CURRENT, A HEAT RADIATION, OR A NEW ELECTRON MOVEMENT OR SHIFTING, WHICH ENABLES IT TO ENTER NEW CHEMICAL UNIONS OR COMBINATIONS WITH ADJACENT SUBSTANCES; THIS ELECTRO-CHEMICAL ACTION IS THE BASIS OF ORGANIC INTEGRATION.

It has been seen that protoplasmic movement is essentially the same in animal or vegetable cells.

Following this reasoning we must understand that sun-energy with its full spectrum of widely varying electron-velocities (or vibration) and the energy of other celestial bodies flooding this planet, are responsible for every electro-magnetic phenomena, including atmospheric conditions, and the combining of atoms to form liquids and solids (see chapter on Electrons). We

know that sun-rays can be transformed into heat-rays, heat-rays into electric currents, electric currents into heat-rays, or light-rays. We know that light or electric current sets up a magnetic field, and that a magnetic field can be made to produce a current, and thus light. What I want to point out clearly is, that without this universal energy known as electric phenomena, there can be no physical motion or life. That energy, a manifestation of chemical change or action, no matter what its nature, is primarily possible and caused by that infinite small particle *known as electron.*

It seems possible that lower forms of life, plant life and even some forms of animal life are merely a collection of atoms, acting under the influence of their environment, which forms them into organization.

There are those who speculate upon the origin of pattern of the protoplasm, arguing that there must be an original pattern, which is the plan so to speak, according to which the organized integration and evolution of protoplasm takes place.

This problem has been attacked from a chemical, a mechanical, a contractural and a dynamic, or transmissive angle. Metaphysics have also entered strongly. Inasmuch as this problem cannot be explained that way, it immediately presents a second problem, that of the pattern of the organism. Speculation on this is as varied and unsatisfactory as in the first problem. One writer has come very near the facts, but cannot see or explain the "third factor." To use his own words:

The dynamic or transmissive factors consist in the transmission through protoplasm or along limiting surfaces of a dynamic change of some sort which is initiated in some particular region. While these factors may involve transportation of electrons or ions from one

point to another, they differ from the transportative factors in that the correlative action of one part upon another is accomplished, not by the mass transportation of substance from one to the other, but by the passage of an energetic change which we call excitation, or of some dynamic effect of excitation. Capacity for transmission of excitation is, so far as we know, characteristic to some degree of all living protoplasm, except, perhaps, in certain quiescent conditions; moreover, protoplasmic transmission may occur from one region to another, even though no differences, either qualitative or quantitative, existed between the two regions before the excitation of one of them by some external factor, i. e., the excitation-transmission pattern may arise, at least momentarily, *through the excitation itself.* The nature of the process of excitation and transmission is, of course, dependent upon protoplasmic pattern, but there is no reason for believing that this protoplasmic pattern can of itself give rise to local excitation in the *absence of external action.* It appears, then, that the *excitation-transmission pattern is in the final analysis the result of action of an external factor upon a protoplasm.*

We have seen that the external factor or exciting factor is the electro-magnetic condition on this planet, existing by reason of solar radiation of electrons.

WHATEVER WAS THE CAUSE OR PATTERN THAT INTEGRATED ATOMS INTO THE PRESENT FORM OF THIS PLANET, MUST ALSO HAVE BEEN THE CAUSE AND PATTERN OF THE ATOMIC COMBINATIONS THAT FORMED THE FIRST PROTOPLASM.

"Since excitation and transmission undoubtedly occur in all protoplasms it is evident that, while the processes concerned may differ in certain respects in

different protoplasms, the occurrence of excitation and transmission is independent of the specific constitution of the particular protoplasm concerned and also independent of the nature of the exciting external factor. Viewed as a whole, the condition which we call excitation, however brought about, appears to be essentially an increase in the rate of living, or at least in the fundamental energy-liberating processes concerned in the life of any particular protoplasm, and transmission consists in the spread or passage of excitation from one region to another, certain dynamic changes in an excited region being the exciting factor for adjoining regions. The excitation-transmission relation is then an energetic, nonspecific or quantitative relation in a protoplasm, and it may therefore be regarded as the most generalized or most primitive organismic relation. This fact is, I believe, of fundamental, though not generally recognized significance for physiology, and particularly in relation to the problem of organismic pattern.

"The conclusion that organismic pattern arises in the final analysis through the relation between protoplasm and environment does not, of course, exclude the possibility that such pattern once established may persist through process of reproduction, i. e., may be inherited." (Charles Manning Child.)

Now, if there is anything dependable, fixed, definable to exact laws, it is the action of electro-chemistry; the behavior of the electron at different velocities, frequencies or vibrations in its relation to atomic combinations. While we do not as yet know or have actually isolated and measured each of the specific possible electronic actions upon the infinite possible atomic combinations, there is enough evidence to assure us that each

correlation is according to a definite scheme, and conditions being equal, will repeat itself; so that the exciting external factor instead of being nonspecific and independent of the pattern of the protoplasm, and the protoplasm or pattern independent of the exciting external factor, the reverse is actually the fact. THE PROTOPLASM PATTERN IS DEPENDENT ON THE EXISTENT "EXCITING FACTOR" (ELECTRO - MAGNETIC - ENVIRONMENT), AND THE ELECTRON MOVEMENT OF THE EXCITING EXTERNAL FACTOR WITHIN THE PROTOPLASM IS SPECIFIC AND ACCORDING TO THE PATTERN OR ATOMIC COMBINATION OF THE PROTOPLASM. This, then, constitutes electro-chemical action. Except the question of where and how it all started, this entirely physical explanation holds good and proves itself, up to a certain stage of organic development, which I will discuss presently.

PRIMITIVE EXCITATION PROCESSES

The question might be raised whether the assumptions concerning the semi-permeability and electric polarization of the plasma membrane and its depolarization in excitation are the only possible basis for the electrical phenomena associated with excitation. It has been pointed out by Lillie and others that acid production and consequent increase in hydrogen ion concentration at points of excitation will not account for the electrical changes, since the currents produced in this way are opposed in direction to those which are actually observed. It is very probable, as Lillie suggests, that the membrane changes may be the primary factors in the highly irritable tissues like nerve, where the process of excitation and transmission and recovery are extremely rapid, but it is possible that in excitation

in general the changes in the membrane may be incidental rather than primary. In an oxidation-reduction cell the electric currents produced show the same relation to the oxidation end of the cell as do the bio-electric currents to the region of excitation. That is, the region where oxidation is going on in the oxidation-reduction cell is externally electro-negative to the region where reduction is occurring. I have repeatedly called attention to the apparent impossibility of dissociating the process of excitation in protoplasm in general from an acceleration of the fundamental dynamic activities of protoplasm, particularly those concerned with the liberation of energy. If current conceptions are correct, the chief source of energy in living protoplasm is oxidation in the electro-chemic sense. Moreover, it is apparently true that a region of rapid oxidation in protoplasm gives rise to electrical conditions similar to those which we observe in relation to the more highly specialized forms of excitation. It is by no means necessary, nor at present justifiable, to maintain that oxidation in protoplasm in regions of less rapid oxidation behaves the same in a region of "excitation" with respect to less excited or unexcited regions, i. e., it becomes electro-negative, and a current similar to the excitation current is set up between it and other less rapidly oxidizing regions. If this current constitutes the exciting factor for adjoining regions and so the primary factor in transmission, then a region of a rapid oxidation, however determined, may initiate a process of transmission which induces excitation, involving an increase in the rate of oxidation at points within range of effectiveness of the current, and so may give rise to an oxidation gradient. Doubtless even in such a case membrane changes are involved, but my point is merely

that they need not necessarily be regarded as the most significant changes in the complex process. In some of his later papers Lillie calls attention to the probable significance of oxidation-reduction in the more primitive excitation-transmission relations.

In such a process as this the velocity of transmission may be very low as compared with nerve, so low indeed that it might in many cases be termed transmission in the ordinary sense. Moreover, in such a process a decrement is to be expected, since a relation unquestionably exists between the electrical condition and the rate of oxidation, and this being the case a gradient must result. In fact, in the extreme case such a gradient may arise without any wavelike transmission of excitation, such as occurs in the nerve, electrical transmission only being involved, and determining a gradation in rate of oxidation and associated conditions from the original region of high rate to a certain limit of distance.

Moreover, if the original region of high rate persists the electrical conditions and so the gradient as a whole must persist and become static instead of advancing in the protoplasm. The length of such a gradient will depend, first, upon the potential arising at the original region of rapid oxidation and, second, upon the conductivity of the protoplasm. In that they represent a gradation from a region of high to one of low physiological activity, such gradients are comparable to the ascending phase or front of an excitation wave in a nerve fiber, viz.: that portion of the wave from the region where excitation is just beginning to the region of maximal excitation. But they differ from the ascending phase of the nervous impulse in that they do not advance, though they may undergo change in length

with change in the rate of reactions in the original region or at other levels.

It seems probable that the most primitive excitation-transmission phenomena in protoplasm possess more nearly the characteristics or such oxidative or metabolic gradients than those of the highly specialized sorts of excitation and transmission processes, such as the nerve impulse. Apparently all gradations exist between the two extremes, and it is at least possible that the more rapidly arising and more rapidly reversible excitation-transmission processes, even in protoplasm in general, are chiefly or wholly plasma-membrane processes, while the slower, more persistent, and less readily reversible processes approach more closely the oxidation gradients and are not necessarily limited to cell membranes, but may occur in relation to limiting surfaces or phase boundaries more or less distant from the surface. But since protoplasm is a system in which a considerable degree of correlation and mutual dependence exists among the essential conditions and reactions, change in any essential factor cannot proceed very far without involving changes in other factors. Undoubtedly, therefore, oxidation is not independent of the condition of membranes or phase boundaries and, on the other hand, the condition of these is not independent of oxidation. In other words, the most primitive and the most highly specialized forms of excitation and transmission in protoplasms probably involve much the same complex of factors, though the specialization of different protoplasmic mechanisms may determine various modifications of the general process with different factors predominant in different mechanisms. It is possible, for example, that in nervous excitation and conduction oxidation may play *a role of minor impor-*

tance and it is even conceivable that in certain protoplasmic mechanisms some *other reaction than oxidation* may be involved.

Again, in some mechanisms the plasma membrane and its changes may be of fundamental importance, while in others this factor may perhaps be secondary and incidental to others. Unquestionably the protoplasmic system affords a basis for the specialization of various mechanisms of excitation and transmission, but it does not follow that the primitive process is exactly like any one of the more highly specialized processes. The general problem has apparently been somewhat obscured by the fact that a large part of the work on excitation and transmission has been concerned with the process as it occurs in the muscle and nerve of the higher animals, and this work has constituted the chief basis of generalization. It is commonly held, for example, that excitation is transmitted as a wavelike change and that it is completely reversible. This is undoubtedly true in large measure for certain protoplasmic mechanisms, but it does not follow that it is true for all or under all conditions. In fact the existence and persistence of the metabolic and physiological gradients in protoplasms without specialized mechanisms indicates, if it does not prove, that neither wavelike transmission of the excitation process nor complete reversibility is a universal characteristic of the excitation-transmission relation. As I have pointed out, the excitation itself does not necessarily travel in these gradients, but the electro-motor changes determine different degrees of excitation at different distances from the point of original excitation. Moreover, in most protoplasms these gradients are not rapidly reversible, but persist after the factors inducing them have ceased

to act, and become factors in determining the developmental order and relation of parts. They are in a sense fixed or static excitation gradients, and the *electrical changes* rather than the excitation itself are transmitted. The various lines of evidence which have been considered seem to me to indicate that the primitive excitation-transmission relation in protoplasm approaches more or less closely this condition and that oxidation is an important factor in it. With the specialization of protoplasm and the appearance of one mechanism or another, changes occur. Perhaps the most significant of these changes is the change in the relation between the exciting factor and the excitation produced. In the more primitive mechanisms, as pointed out above, the energy, the intensity, or, in lack of definite knowledge we may say the degree of excitation, is certainly under some, if not all, conditions a function of the energy, the intensity, or the effectiveness of the exciting factor, and the protoplasm is capable of *different degrees* of excitation. But with the specialization of mechanisms of excitation and transmission, the relation apparently becomes more and more like that of the spark and the powder, and such specialization reaches its final terms in the more highly differentiated muscle and nerve which apparently react according to the "all-or-none" law, i. e., maximal excitation results from any stimulus above the threshold. Under these circumstances transmission of the *excitation as a wave to an indefinite distance without decrement is possible,* provided the maximal excitation at successive points of the path does not decrease; in other words, provided the path is not already a physiological gradient."

We know that this is exactly the case in nerve impulse transmission. The facts indicate that between the

primitive gradient in which transmission depends entirely upon conditions at the point of original excitation and the condition of transmission without decrement various intermediate conditions exist, even in the same organism at different stages of development and perhaps in some cases with different degrees of excitation.

GENERAL DISCUSSION

Concerning the existence of the axial gradients and their significance in development there can be no doubt. These are demonstrated facts, however we may interpret them, and they are the earliest indications of an order or pattern on a larger scale than that of protoplasm.

Organismic pattern is, as already noted, a pattern of regions or masses of protoplasm or cells and of a higher order of magnitude than protoplasmic pattern; physiological polarity and symmetry appear in protoplasms of very different specific constitution and many different lines of evidence agree in indicating that they are primarily quantitive gradations in physiological condition, and that they can be determined experimentally in many protoplasms by differential exposure of the cell or cell mass to the action of an external factor. In some protoplasms the gradients are only transient. In *amœba,* for example, the ectoplasm of the pseudopod is a gradient for the time being, but here the changes which give rise to the gradient are readily reversible and no permanent axiation develops. (Hyman, 1917.) In most protoplasms, however, the changes are less readily reversible, and a definite axiation results which may persist even through reproductive processes. The development of the axial gradient

is merely one feature of development in axiate forms, and it represents the first steps in the localization of physiological differences of organismic magnitude in the protoplasm concerned. The course of further development and differentiations is determined by the specific hereditary mechanism of each particular protoplasm and the gradient is merely the framework, the ground plan on which the complex superstructure arises.

We have seen that in the simpler forms and earlier developmental stages the axial gradient is very commonly found only in the superficial regions of the body. In most protozoa and differential plant cells this superficial region is apparently denser and more permanent in position and structure than other regions of the cytoplasm, and if the gradient is an excitation gradient it may be expected to appear primarily or chiefly in relation to limiting surfaces, and its persistence is possible only in those regions in which the protoplasm substratum possesses a certain degree of stability. But, admitting that excitation is transmitted along limiting surfaces, such surfaces are present, not only at the cell surface, but may be more or less continuous in the interior according to the phase relations. There is no reason why excitation should not be transmitted along these internal limiting surfaces, so far as they are continuous, and in this way penetrate the protoplasm to a greater or lesser depth. The internal limiting surfaces are doubtless not identical with the external, and conditions in them may be less favorable, but there are no grounds for believing that internal transmission is impossible. If it is possible, the axial gradients may exist not only at the surface, but to a greater or lesser depth in protoplasm, according to conditions, and may in

some cases involve the whole cell, as is apparently the case in some eggs. This suggestion also bears upon the question of cell pattern and surface-interior pattern in general. I believe, in short, that the interpretation of axiate pattern in terms of excitation and transmission and the more or less persistent developmental protoplasmic changes which result from it, not only to be the simplest interpretation possible on the basis of our present knowledge, but the interpretation which accounts most satisfactorily for all known facts. (Charles Manning Child.)

It is impossible to review the literature of the subject here, but it is of interest to note that many authors have suggested that *polarity* is a gradient of some sort. Morgan (1904, 1906, 1907), for example, has at various times advanced the idea of polarity as a gradation or stratification of materials. Boveri (1910) maintained that the polarity of the Ascaris egg must be a gradation of some sort, and numerous authors have described gradations in size or form of parts, rate of development or regeneration, etc., along the chief body axis. In fact, evidence of one kind or another for the existence of gradients of some sort as characteristic features of axiate organisms appears in the literature of many different and widely separated fields of investigation, both physiological and morphological. This evidence is perhaps the more valuable because the authors were in most cases stating or describing facts rather than attempting to formulate theories. In the conception of the excitation gradient and its fixation in protoplasm I have merely attempted to provide a general physiological basis for the facts as they stand.

There is evidence that when such organizations come to a critical stage of development another factor exists,

that of intelligence or consciousness. Some manifestations as, plants that catch living animals for nourishment, propagation or reproduction by sex, defense and protection against destruction from enemies or natural elements, are well known and leave no doubt as to the existence of a consciousness or intelligence in such organisms. (See chapter, The Psychical Processes.)

As has been seen, all active cells have a similar pattern in so far that the nucleus is more acid than the cell body; the difference of potential, i. e., the setting up of an electro-motive force, an electron or heat radiation, created by this difference in reaction is apparently necessary for the performance of its work, as well as for its survival. All cells excepting the brain cells are provided within themselves with an efficient mechanism, that is, atomic combinations, that will defend them, or make use of conditions arising from acidosis. When the acidity of the cytoplasm and the nucleus become equalized by reason of introduction of foreign atoms, or a lack of electro-magnetic environment, the cell ceases to function; it dies. So that this difference of potential in the cell is the foundation on which physical life rests. It seems a fact that the constant production of acids in the cytoplasm as a part of the process of living eventually kills the cell.

From important observations of Hardy's it appears extremely probable that many of the protein constituents which may be isolated from the various tissues and tissue-fluids do not pre-exist there but are bound up in complex compounds of proteins with proteins. I quote from the appendix to Hardy's article on globulin:

"The facts of the case are these. The proteins of serum are electrically inactive. Neither the whole nor

any fraction moves in a field. It is not possible to detect a trace of 'ionic' protein. Dialysis or dilution disturbs the equilibrium and 'ionic' globulin appears, and can be swept out of the general mass of proteins as an opalescent cloud before dialysis has been pushed to the point where precipitation occurs. The development of even minute quantities of 'ionic' globulin can be detected in this way. The direction of the movement is toward the anode, therefore the globulin which appears is the anion of alkali-globulin."

"Serum which has been dialyzed against water with low carbonic acid content until it ceases to give any precipitate, but which can still give with acid a large yield of globulin, is in a most interesting condition. The whole remaining protein is now ionic. It moves toward the anode quite uniformly, therefore it behaves as a whole as the protein ion of an alkali protein compound."

"Now what does this mean? The presence of other proteins does not interfere with the movement of ionic protein. This point cannot be too much insisted on. It lies at the root of the evidence. Therefore one starts with protein which behaves uniformly and is electrically inactive, one ends with protein which behaves uniformly and is electrically active, and in the final stage there is no evidence of more than one kind of protein ion. But this residue of uniform character still contains a globulin fraction. It can be split by saturation with a neutral salt or by acidulation into fractions differing in properties according to the mode of separation."

"When in the cell used for experiments, the upper layer of fluid is a solution of 1/600th normal acetic and the lower layer is serum and a current is passed for 24

hours, the serum protein becomes slowly charged in such a way that it is repelled from both poles. Therefore, in the anodic limb it becomes charged positively, in the cathodic limb negatively. The result of the double repulsion is that the protein is condensed into a hard plate of rubber like consistency just midway between the electrodes."

"The phenomena would be explained, on the theory which has been outlined, in this way. In the anodic limb an excess of hydroxyl ions are liberated owing to the electric convection, and these, reacting with the serum protein, convert it into cationic protein. In the cathodic limb the converse reaction with hydrions occurs and is possible owing to the amphoteric nature of proteins. The entire mass of serum protein is thus thrown into the ionic state and in this condition moves with uniform motion, the one-half as cationic protein, the other half as anionic protein. The electric current, the most subtle analysis, detects only one substance, and this substance, owing to the amphoretic nature can exist in either the cationic or the anionic state."

"The position is that in serum one has protein which can be thrown into the ionic state and which then moves in a field as a single substance. From it an electrically active fraction, namely globulin, can be split off, and the protein thereby becomes electrically heterogeneous."

"Now the globulin fraction has an abiding characteristic. In all its solutions its molecular state is so gross as to cause the molecules to be arrested by a porous pot. They will not pass such a filter even under pressure. In this it is sharply distinct from the parent serum protein, which is readily filterable. If globulin be present as such in serum it is not only non-ionic but

the agent which dissolves it must be something more than alkali and salt since either alone or together they will not produce so high a grade of solution."

"The difference in the molecular grade of globulin when once separated, and the electrical homogeneity of serum protein and of the fraction (still capable of further subdivision by salting out) which remains after the alkaline globulin fraction which most readily appears has been removed suggests that serum protein is a complex unit. If such a unit exists it is not saturated with globulin. Fresh ox-serum has an extraordinary power of dissolving globulin, it will take up almost its own volume of the thick cake at the bottom of a centrifuge tube; and in ox-serum so saturated there is not a trace of alkali globulin nor any ionic protein."

CHAPTER VI

PHYSIOLOGICAL DEVELOPMENT OF THE NERVOUS SYSTEM

MODERN science almost unanimously agrees that the origin of a nervous system in protoplasm does not involve new functional activities differing from the primitive electro-chemical actions of protoplasm, and their integration into more complex organisms. The same factors of excitation and transmission depending on the primary atomic structure and the electro-magnetic condition of the moment are the causes of nerve development. If we admit that the physiological gradients originate from these causes, then the developmental relations between these gradients and nervous structure and function become highly significant.

The first localization of nervous differentiation is to be found in the surface-interior pattern; the primary receptors develop at the surface; even in the neutral tube of vertebrates we find indications of the influence of the surface-interior factor in the localization and direction of outgrowth of the earlier axons. In animals with highly developed axiate pattern, the chief receptors and aggregations of nervous tissue differentiate from the high ends of the chief body gradients.

This relation is most conspicuous with respect to the major or polar gradient, the apical end of the head, with its special sense organs and nervous ganglia, arising from the high end of the gradient. These sensory cells with their tentacles, from their first appearance as buds show a definite physiological gradient with differences in electrical potential, susceptibility, etc., and

there is no other alternative but that the further growth of nerve fibers is determined by this pre-existing gradient.

It has long been known that in the development of pieces isolated from the body of various species of hydroids, flat worms, and annelids, the apical or anterior region of the pieces, give rise to an apical structure, or head, irrespective of the level of the body from which the piece was taken. In this connection it is of interest to note that Flaxner, 1898, and Keiller, 1910, have shown that in the regenerating head of planeria the ganglia may develop quite independently of the cut ends of the nerve cords in the piece and the connections are established later by outgrowth from the ganglia rather than from the nerve cords. Goldfarb, 1909, removed the nerve cord from several segments at the anterior cut end of pieces of earth worm and found that the head and the ganglia developed normally in such pieces, and the nerve cords grew posteriorly from the new head into the old parts, although some regeneration in the anterior direction from the end of the old cord occurred. In this case it is demonstrated beyond question that the ganglia in the regenerating head developed independently of other parts of the nervous system in the piece. There is no getting away from the fact that the apical or cephalic portion of the central system develops independently of subapical or postcephalic regions. Its physiological independence are simply two aspects of the same condition and both are results of the fact that this portion of the central nervous system develops from the high end of the primary gradient, that is, from that region of the body in which activity is most intense in its earliest stages. In fact the development of the central nervous system and

particularly of its cephalic portion represents that physiological reaction of animal protoplasm which is least complicated by physiological correlation with other parts, and most directly related to the existing electromagnetic energy. From now on the central nervous system becomes the chief organ of excitation and transmission and of physiological integration, its future integration being of course based on the hereditary constitution of the original protoplasmic combination.

Ritter, 1919, and Johnson, 1910, have called attention to the significance of the repetitive process of segmentation as evidence of law and order in organisms and their bearing on the problem of integration. Segmentation as a physiological process begins in the most active layer, the ectoderm, and it resembles various processes of agamic reproduction. The problem of segmentation of the vertebrate head has been widely discussed and an extensive literature exists which cannot be gone into here but the general consensus is, that the segmentation of the cephalic and in fact of the whole central nervous system of the vertebrate, appears in the adult in the arrangement of cranial and spinal nerves, spinal ganglia, and in certain parts in the arrangement of centers or nuclei of the nerves.

There is no evidence that the embryonic development is not exactly the same.

Sherrington, 1906, has demonstrated that the central nervous system (centralization) is the process both ontogenetic and phylogenetic of localization and aggregation, in fact it is integration. The evolutionary progress of nervous cephalization is accompanied by various other changes in form, proportion and relations of parts, particularly in the segmented animals in which the fusion of segments at the anterior end of the body,

the decrease in total number of segments, and the increasingly intimate physiological relations of the segments in general, are characteristic features. By evolutionary progress or change, we must necessarily mean that the hereditary potentialities of protoplasm are altered in the course of evolution, in other words, the reaction of the protoplasm to the conditions giving rise to a gradient must undergo modification in the course of evolution like other protoplasmic reactions. The physiological basis is the same.

The extensive investigations of Golgi, Ramon Y. Cajal, Ehrlich, Retzius, Bethe, and many others have given us a very complete knowledge of neuron pattern and some detailed description of this is given in a later chapter on the general physiology of nerves. In general the same facts prevail; both axon and dendrites in neuron pattern are primarily physiological gradients. The axon is a highly specialized outgrowth, whose chief function is evidently conduction. It has little or no direct nutritive relation with its environment, except perhaps in earlier stages of its development. Its growth and its maintenance depend upon its connection with the cell body. There can be no doubt, however, that the dendrites are important nutritive organs as well as conductors of impulses. In all probability they are primarily nutritive and continue this function after they become conductors. The axon arises in a definite direction for at least some distance, but the dendrites very commonly arise on various regions of the cell surface, often on all sides of it, and grow in all possible directions, at least during the earlier stages. The one exception to this is the pyramidal cell of the cortex. The primary dendrite develops on the opposite side of the cell from the axon and grows at first, or continuously

in a definite direction. The absence of definite orientation of the dendrites of some neurons in earlier stages, and the sudden changes in direction of growth of both axon and dendrites, make it necessary to assume that the reaction of the outgrowth changes, or that the concentration gradients of the substances change their direction, or that new substances appear with concentration gradients in different directions from those of the original substances. Any of these actions are within our explanation of the phenomena, and the following facts substantiate all our assumptions. The existence of the axial physiological gradients and of gradients in electrical potential as one of their characteristics, has been demonstrated beyond question, and we find a very definite relation between the directions of growth of the axons which arise in the earlier stages of development, and these gradients.

In regions of rapid growth in the nervous system as well as in other organs we find changes in electrical potentials. Admitting this it is evident that in the course of development there must be changes both in the intensity of potential, and in the direction of the potential gradients. Another fact is that conduction of nervous impulse is accompanied by marked change in electrical potential. As soon as any neuron group or axon, or axon bundle, becomes functionally active in this way, changes in the potential gradients in its vicinity must appear. In short, the existence of gradients in electric potential with the resulting electric currents, and the changes in direction and intensity of these gradients during development, and in relation to function, must be a factor in determining the physiological conditions of the cells affected, and so constitute a real reason for the problem of neuron development.

Extensive work has been done by Dr. R. G. Harrison and Dr. Ingvar in the determination of the direction of outgrowth of neuro-blasts in tissue culture by means of electrical currents, and this work represents the first step in experimental determination of polarity in neuro-blasts. Whole books can be and have been written on the subject attacking the problem first from a purely chemical, then from a purely electrical standpoint. The results are ever the same; we can find in the fundamentals of electron movements and electro-chemistry, the principles that account for the origin and evolution of the nervous system.

Nerve conductivity has always been studied in connection with the evolution and development of the nervous system, but the widely differing functions which nerve impulses can assume have puzzled most investigators and have given rise to many speculations and voluminous literature on the subject. The most outstanding and important factor which has a direct bearing on the functions and results of nerve impulses are those connections between dendrites and axons which are termed synapsis. (This problem is to be fully treated in a special chapter on Synapses.)

CHAPTER VII

NERVE STRUCTURES—CHEMISTRY OF NERVOUS TISSUES

NERVOUS tissue is the material of which the nervous system is composed. The nervous system is composed of two parts, the *central nervous system* and the *peripheral nervous system.* The central nervous system consists of the brain and spinal cord; the peripheral system consists of the nerves, which conduct the impulses to and from the central nervous system, and thus bring the nerve centers into relationship with other parts of the body.

Some of the nerves conduct impulses from the nerve centers and are called *efferent;* those which conduct impulses in the opposite direction are called *afferent.* This distinction between efferent and afferent nerves is a physiological one, which we shall work out more thoroughly later on. No histological distinction can be made out between motor and sensory nerves.

Under the microscope nervous tissue is found to consist essentially of *nerve cells* and their branches. The nerve cells are contained in the brain and spinal cord, and in smaller collections of cells on the course of the nerves called *ganglia.* The part of the nerve centers containing cells is called *gray matter.*

Long branches of the nerve cells are known as *nerve fibers.* These become sheathed in a manner to be immediately described, and are contained in the nerves, and in the *white matter* of brain and spinal cord. The bodies of nerve cells differ in size, shape and arrangement, and we shall discuss these fully when we get to

the nerve centers. For the present it will be convenient to confine ourselves to the nerve fibers as they are found in a nerve.

Nerve fibers are of two histological kinds, *medullated* and *non-medullated.* Medullated nerve fibers are found in the white matter of the nerve centers and in the nerves originating from the brain and spinal cord. Non-medullated nerve fibers occur in the sympathetic nerves.

MEDULLATED OR WHITE FIBERS

The medullated or white fibers are characterized by a sheath of white color, fat-like in nature, and stained black by osmic acid; it is called the *medullary sheath,* or *white substance of Schwann;* this sheath is the essential part of the fiber which is a process from a nerve cell, and is called the *axis-cylinder.* Outside the medullary sheath is a thin homogenous membrane of elastic nature called the *primitive sheath* or *neurilemma.*

The *axis-cylinder* is a soft transparent thread in the middle of the fiber; it is made up of exceedingly fine fibrils, which stain readily with gold chloride. The *medullary sheath* gives a characteristic double contour and tubular appearance to the fiber. It is interrupted at regular intervals known as the *nodes of Ranvier.* The stretch of a nerve fiber between two nodes is called an *inter-node,* and in the middle of each inter-node is a nucleus which belongs to the primitive sheath. Besides these interruptions, a variable number of oblique clefts are also seen dividing the sheath into *medullary segments;* but most if not all of these are produced artificially in the preparation of the specimen.

The medullary sheath also contains a horny substance called *neurokeratin;* the arrangement of this substance

is in the form of a network or reticulum holding the fatty matter of the sheath in its meshes. The occurrence of horny matter in the epidermis, in the development of the enamel of teeth, and in nerve, is an interesting chemical reminder that all these tissues originate from the same embryonic layer, the epiblast. The fat-like matter consists largely of *cholesterin,* a monatomic alcohol, and phosphorized fats, such as *lecithin.*

Near their termination the nerve fibers branch; the branching occurs at a node.

Staining with silver nitrate produces a peculiar appearance at the nodes, forming what is known as the *crosses of Ranvier.*

One limb of the cross is produced by the dark staining of cement substance which occurs between the segments of the neurilemma; the other limb of the cross is due to the staining of a number of minute transverse bands in the axis-cylinder (Fromann's lines), which is here not closely invested by the medullary sheath. Macallum has shown that this appearance of transverse striping is an artifact, and can be obtained in any exposed portion of an axis-cylinder, that is, wherever the silver nitrate can penetrate to it.

ARRANGEMENT OF NERVE FIBERS

The arrangement of the nerve fibers in a nerve is best seen in a transverse section.

The nerve is composed of bundles of *finiculi* of nerve fibers bound together by connective tissue. The sheath of the whole nerve is called *epineurium;* that of the funiculi the *perineurium;* that which passes between the fibers in a funiculus, the *endoneurium.* Single nerve fibers passing to their destination are surrounded by a prolongation of the perineurium, known as the

sheath of Henle. The nerve trunks themselves receive nerve fibers which ramify and terminate as end-bulbs in the epineurium.

The size of the nerve fibers varies; the largest fibers are found in the spinal nerves, where they are 14.4 to 19 micro-millimeters. Others mixed with these measure 1.8 to 3.6 micro-millimeters. These small nerve fibers are visceral nerves; they pass to collections of nerve cells called the sympathetic ganglia, whence they emerge as non-medullated fibers, and are distributed to involuntary muscle. They are well seen in sections stained by osmic acid, the black rings being the stained medullary sheaths.

NON-MEDULLATED FIBERS

The non-medullated fibers or *fibers of Remak* have no medullary sheath, and are therefore devoid of the double contour of the medullated fibers, and are unaffected in appearance by osmic acid. They consist of an axis-cylinder covered by a nucleated sheath. They branch frequently.

STRUCTURE OF NERVE CELLS

Nerve cells differ a good deal both in shape and size.

In the early embryonic condition, the future nerve cell is a small nucleated mass of protoplasm without processes. As development progresses branches grow, and by this means it is brought into contact with the branches of other nerve cells. When the nerve cells degenerate, as they do in some cases of brain and cord disease, there is reversal of this process; just as in a dying tree, the terminal branches, those most distant from the seat of nutrition, are the first to wither, so it is in the degenerating nerve cell. If one traces the

structure of nerve cells throughout the zoological series, there is also seen an increase in their complexity, and the number of points of contact, produced by an increase in the number and complexity of the branches, multiplies.

The simplest nerve cells known are termed *bipolar*. In the lower animals the two processes come off from the opposite ends of the cells; the cell, in other words, appears as a nucleated enlargement on the course of a nerve fiber. The cells of the Gasserian and spinal ganglia in the mammalian embryo are also bipolar, but as development progresses, the two branches become fused for a considerable distance, so that in the fully formed animal each cell appears to be *unipolar*.

The bifurcation of the nerve fiber is spoken of as a T-shaped junction. The nerve process has a convoluted course on the surface of the cell before it bifurcates. In these ganglia it should be also noted that each cell is enclosed within a connective tissue sheath, and the nuclei seen are those of the connective tissue corpuscles.

The majority of nerve cells found in the body are multipolar. Here the cell becomes angular or stellate. From the angles of the cell, branches originate; the majority of these branches divide and subdivide until each ends in an arborescence of fine twigs or fibrils; but one process, and one process only, of each cell becomes the axis-cylinder of a nerve fiber.

Passing next to the central nervous system, we here again find the multipolar cell is the principal kind present.

Here again, only one process becomes the axis-cylinder of a nerve fiber, and the others break up into arborizations of fibrils. The cells have a finely fibrillar

structure, and the fibrils can be traced into the axis-cylinder process and the other branches of the cell. Between the fibrils the protoplasm of the cell contains a number of angular or spindle-shaped masses, which have a great affinity for basic aniline dyes like methylene blue. They are known as *Nissl's granules.* These nerve cells often contain, especially in the adult, granules of pigment, usually yellow, the nature of which has not been determined.

In preparations made by Golgi's chromate of silver method, the cells and their processes are stained an intense black by a deposit of silver. The various structures in the cells (nucleus, granules, fibrils, etc.) are not visible in such preparations, but the great advantage of the method is that it enables one to follow the branches to their finest ramification. It is thus found that the axis-cylinder process is not unbranched, but invariably gives off side-branches, which are called *collaterals;* these pass into the adjacent nerve tissue. The axis-cylinder then acquires the sheaths, and thus is converted into a nerve fiber. This nerve fiber sometimes, as in the nerve centers after a more or less extended course, breaks up into a terminal arborescence enveloping other nerve cells; the collateral also terminates in a similar way. The longest type of axis-cylinder is that which passes away from the nerve center, and gets bound up with other similarly sheathed axis-cylinders to form a nerve; but all ultimately terminate in an arborescence of fibrils in various end-organs (end-plates, muscle, muscle spindles, etc.).

In the gray matter of the cerebrum the nerve cells are various in shape and size, but the most characteristic cells are pyramidal shape. They are especially large and numerous in what are called the motor areas

of the brain. The apex of the cell is directed to the surface; the apical process is long and tapering, and finally breaks up into fibrils that lie parallel to the surface of the brain (*tangential fibers*). From the lower angles and other parts branching processes originate; the axis-cylinder comes off from the base of the pyramid.

The gray matter of the cerebellum contains a large number of small nerve cells and one layer of large cells. These are flask shaped, and are called the *cells of Purkinje.* The neck of the flask breaks up into branches, and the axis-cylinder process comes off from the base of the flask.

CHEMISTRY OF NERVOUS TISSUES

Fresh nervous tissue is alkaline to litmus, but like most other living structures, it turns acid after death; this change is more rapid in gray than in white matter. The acidity is due to sacro-lactic acid.

Nervous tissues contain a high percentage of water and proteins.

PROTEINS

In gray matter where the cells are prominent this is most marked, protein here comprising more structures than half of the solids present.

The most abundant protein is nucleo-protein, and micro-chemical observations have shown that the granules in nerve cells (Nissl's granules) which stain readily with methylene blue and other basic dyes are nucleo-protein in nature. There is also a certain amount of globulin, which, like the paramyosinogen of muscle, is coagulated by heat at a low temperature (in

mammals 47° C.) Neurokeratin, which is especially abundant in white matter, is also present.

A nerve, or a strip of the central nervous system, shortens when it is heated; this "heat contraction" occurs in a series of steps, which, as in the case of muscle, take place at the coagulation temperature of the proteins present. The first step in the shortening occurs in the frog at about 40°, in the mammal at about 47°, and in the bird at about 52° C. The nerve is killed at the same temperature.

LIPOIDS

These are also abundant constituents of nervous tissue; their action is more fully studied in the chapter on Electro-Chemistry of Proteins; we will, therefore, merely state that they compromise:

1. *Phosphatides,* or phosphorized fats. Of these lecithin is the best known; kephalin and sphingomyelin are others.

2. *Galactosides.* These are nitrogenous glucosides from phosphorous; they yield on hydrolysis the reducing sugar galactose.

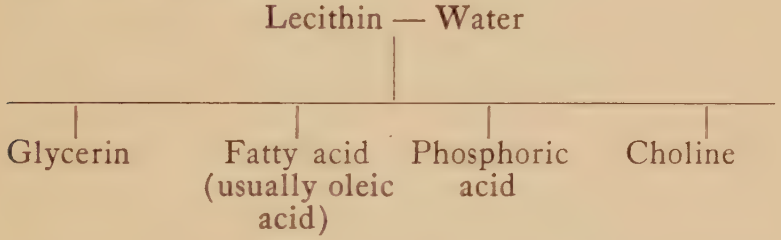
3. *Cholesterin* or *cholesterol.* A crystalline monatomic alcohol of the terpene series. Its formula is C_{27}, H_{45} *OH*.

The following are some recent analyses of nerve by Falk; the numbers given are percentages of the total solids:

	Medullated Nerve	Non-Medullated Nerve
Cholesterin	25.0	47.0
Lecithin	2.9	9.8
Kephalin	12.4	23.7
Galactosides	18.2	6.0

Lecithin is a type of the phosphatides, and we may contrast its decomposition products with those obtained from a fat. An ordinary fat contains the elements carbon, hydrogen, and oxygen, and when it takes up water it is split or hydrolyzed into its constituent parts, glycerin and fatty acid.

Lecithin (C_{42}, H_{84}, NPO_9) contains not only carbon, hydrogen and oxygen, but nitrogen and phosphorous as well. When it is hydrolyzed, it yields not only glycerin and fatty acid, but also phosphoric acid, and a nitrogenous base termed choline.



Choline is an ammonium-like base, which contains three methyl (CH_3) groups. Its formula is $N\ (CH_3)_3$, CH_2, $CH_2\ (OH)_2$, and when it breaks up, trimethylamine, $N\ (CH_3)_3$, is one of its decomposition products.

EXTRACTIVES

Small quantities of numerous other organic substances are included under this general term; croatins, xanthine, hypo-xanthine, inosite, lactic acid, uric acid, and urea have been identified.

INORGANIC SALTS

The proportion of mineral salts amounts to a little more than 1 per cent of the total solids. Potassium salts are the most abundant. We have already noted that Macdonald attributes many of the phenomena of

nervous action to electrolytic changes in these potassium salts.

CHEMICAL CHANGES IN NERVOUS TISSUES DURING ACTIVITY

This is an almost unknown field. No change of reaction can be detected in nerves after the most prolonged stimulation. The only thing known for certain is that oxygen is essential, especially for the activity of gray matter; cerebral anæmia is rapidly followed by loss of consciousness and death. The slight respiratory changes can be detected in peripheral nerves. It can hardly be doubted that phosphatides, which are extremely labile substances, participate in metabolism; and Hans Meyer has pointed out that anæsthetics such as chloroform and ether are soluble in lipoids, and that this interaction may, by lessening oxidative processes, lead to the production of unconsciousness.

Cerebro-spinal fluid. This plays the part of the lymph of the central nervous system, but it differs considerably from all other forms of lymph. It is a very watery fluid, containing besides some inorganic salts similar to those of the blood, a trace of protein matter (globulin) and a small amount of sugar. Normally it contains neither nucleo-protein, cholesterin, or choline, and practically no cells. Colorless corpuscles, however, occur in it in inflammatory conditions. There is no doubt that the fluid is a true secretion, and that the cells which secrete it are the cubical epithelial cells which cover the choroid plexuses. The choroid structure may indeed be spoken of as the *choroid gland;* only it differs from other glands in having the secreting epithelium on its outer surface. (References from Halliburton.)

CHAPTER VIII

THE PHYSIOLOGY OF NERVES (GENERAL)

THE physiology of the nervous system is well covered in standard text books. Therefore, in this work, we confine ourselves only to such phases of general nerve physiology as are necessary for the understanding of the subject under discussion.

The nerve fibers which form the conducting portions of the nervous system may be classified into three main groups, according to the direction in which they normally conduct nerve impulses. These three classes are:

1. Efferent nerve fibers.
2. Afferent nerve fibers.
3. Inter-central nerve fibers.

1. Efferent or centrifugal nerves are those which conduct impulses from the central nervous system (brain and spinal cord) to other parts of the body. When, for instance, there is a wish to move the hand, the impulse starts in the brain, and travels a certain distance down the spinal cord; it leaves the spinal cord by one or more of the spinal nerves, and so reaches the muscles of the hand, which are thrown into contraction. Such nerves are called motor. A list of the classes of efferent nerves is as follows:

a. Motor.
b. Accelerator.
c. Inhibitory.
d. Secretory.
e. Electrical.
f. Trophic.

a. Motor nerves. Some of these go to voluntary muscles; others to involuntary muscles, such as the vaso-motor nerves which supply the muscular tissue in the walls of arteries.

b. Accelerator nerves are those which produce an increase in the rate of rhythmical action. An instance of these is seen in the sympathetic nerves that supply the heart.

c. Inhibitory nerves are those which cause a slowing in the rate of rhythmical action, or it may be its complete cessation. Inhibitory nerves are found supplying many kinds of involuntary muscle; a very typical instance is found in the inhibitory fibers of the heart which are contained within the trunk of the vagus nerve.

d. Secretory nerves are found supplying many secreting glands, such as the salivary glands, gastric glands, and sweat glands. The impulse which travels down a secretory nerve stimulates secretion in the gland it supplies.

e. Electrical nerves are found in the few fish which possess electrical organs. The impulse which travels down these nerves causes the electrical organ to be thrown into activity.

f. Trophic nerves are those which control the nutrition of the part they supply.

2. Afferent or centripetal nerves are those which conduct impulses in the reverse direction, namely, from all parts of the body to the central nervous system. When one feels pain in the finger, the nerves of the finger are stimulated, an impulse travels up the nerves to the spinal cord, and then to the brain. The mental process set up in the brain is called a sensation; the sensation, however, is referred to the end of the nerve where the impulse started, and the sensation of pain does not appear to occur in the brain, but in the finger.

This is an instance of a sensory nerve; and the terms afferent and sensory may often be used synonymously. The nerves of sensation may be grouped as follows:

a. The nerves of special sense; such as, sight, hearing, taste, smell, and touch.
b. The nerves of general sensibility; that is, a vague kind of sensation not referable to any of the special senses; for instance, we may take the vague feelings of comfort or discomfort in the interior of the body.
c. Nerves of pain. It is a moot point whether these are anatomically distinct from the others, but there is some evidence that this is the case.

The words "sensory" and "afferent," however, are not quite synonymous. Just as we may have efferent impulses leaving the brain for the heart or blood vessels of which we have no conscious knowledge, so also afferent impulses may travel to the central nervous system which excite no conscious feelings. The afferent nerve tracts to the cerebellum form a very good instance of these.

Then, too, the excitation of many afferent nerves will excite what are called reflex actions. We are very often conscious of the sensations that form the cause of a reflex action, but we do not necessarily have such sensations. Many reflex actions, for instance, occur during sleep; many may be executed by the spinal cord even after it has been severed from the brain, and so the brain cannot be aware of what is occurring.

A reflex action is an action which is the result of an afferent impulse. Thus a speck of dust falls into the eye, and causes movements of the eyelids to get rid of the offending object. The dust excites the sensory nerve endings in the conjunctiva, an impulse travels to

the center of this nerve in the brain, and from the brain a reflected impulse travels to the muscles of the eyelid. As an instance of a reflex action in which secretion is concerned, take the watering of the mouth which occurs when food is seen or smelled. The nerves of sight or smell convey an afferent impulse to the brain, which reflects, down the secretory nerves, an impulse which excites the salivary glands to activity.

These, however, are instances of reflex action and are accompanied with conscious sensation, but like all pure actions are not under the control of the will.

An instance of a reflex action not accompanied with consciousness is seen in a man with his spinal cord cut across or crushed, so that any communication between his brain and his legs is impossible. He cannot move his legs voluntarily, and is unconscious of any feeling in them. Yet when the soles of his feet are tickled he draws his legs up, the center of reflex action being in the gray matter of the lower region of the spinal cord.

For a reflex action, three things are necessary: (1) an afferent nerve, (2) a nerve center consisting of nerve cells to receive the afferent impulse and send out the efferent impulse, and (3) an efferent nerve along which the efferent impulse may travel. If the reflex action is a movement, the afferent nerve is called excito-motor; if it is a secretion the afferent nerve is called excito-secretory; and, similarly, afferent nerves may also be excito-accelerator, excito-inhibitory, etc.

3. Inter-central nerve fibers are those which connect nerve centers together; they connect different parts of brain, and of the cord to one another, and we shall find in our study of the nerve centers that they are complex in their arrangement.

A close study of the foregoing explains at once why

spinal adjustments given according to certain set rules are sometimes successful, and at other times do not seem to have the usual and desired effect.

There are always two main experiments by which the function of a nerve may be ascertained. The first is section, the second is stimulation.

Section consists in cutting the nerve and observing the loss of function that ensues. Thus, if a motor nerve is cut, motion of the muscles it supplies can no longer be produced by activity of the nerve center; the muscle is paralyzed. If a sensory nerve is cut, the result is loss of sensation in the part it comes from.

Stimulation of the cut nerve is the opposite experiment. When a nerve is cut across, one piece of it is still connected with the brain or spinal cord; this is called the central end; the other piece, called the peripheral end, is still connected with some peripheral part of the body. Both the central and the peripheral end should be stimulated; this is usually done by means of induction shocks. In the case of a motor nerve, stimulation of the central end produces no result; stimulation of the peripheral end produces a nervous impulse which excites the muscles to contract. In the case of a sensory nerve, stimulation of the peripheral end has no result, but stimulation of the central end causes a sensation, usually a painful one, and reflex actions, which are the result of the sensation.

When a nerve is cut across, there are other results than the loss of function just mentioned; for even though the nerve is still left within the body with a normal supply of blood, it becomes less and less irritable, till at last it ceases to respond to stimuli altogether. This diminution of excitability starts from the point of section and travels to the periphery, but is tempo-

rarily preceded by a wave of increased excitability traveling in the same direction (Ritter-Valli law).

This loss of excitability of nerve is accompanied with degenerative changes which are of so great importance as to demand a separate section.

The view that in the embryo each nerve fiber develops as an outgrowth from a nerve cell, and grows in a distal direction, finally becoming united to other tissues in the periphery of the body, is associated especially with the name of His, and has been accepted by the majority of embryologists. There have been other views held, but it will be sufficient to mention only one of these, for it is the one which, next to that of His, has been favored by investigators. Briefly, it is as follows: The nerve fiber is not a secondarily formed bridge between the central nervous system and the peripheral organs, *but exists from the very first,* and in subsequent development it merely undergoes elaboration, and increases in bulk and in length as the distance from the central nervous system and the periphery increases with the increasing size of the developing organism.

Mr. Ross Harrison of the Johns Hopkins University, Baltimore, has actually seen the fibers growing outwards in embryonic structures. Pieces of the primitive nervous tube which forms the central nervous system were removed from frog embryos, and kept alive in a drop of lymph for a considerable time; the cilia of the neighboring epidermic cells remained active for a week or more; embryonic mesoblastic cells in the vicinity were seen to become transformed into striated muscular fibers, and there was therefore no doubt that even under artificial conditions of this kind—rendered necessary for microscopic purposes—life and growth

were continuing. From the primitive nerve cells, and from these alone, nerve fibers were observed growing and extending into the surrounding parts. Each fiber shows faint fibrillation, but its most remarkable feature is its enlarged end, which exhibits a continual change of form. This amœboid movement is very active, and it results in drawing out and lengthening the fibers to which it is attached, and the length of the fiber increases at the rate of about a micro-millimeter in one or two minutes. Similar observations have since been made in the embryos of other animals.

These observations show beyond question that the nerve fiber develops by the overflowing of protoplasm from the central cells, and thus give us direct evidence in favor of the view which most embryologists previously held mainly as the result of circumstantial evidence. (See chapter on Cells.) Such, then, being the general state of our knowledge regarding the way in which nerve fibers grow in the developing animal, it is not surprising to find that the prevalent idea regarding their regeneration after injury follows the same lines. The original teaching of the elder Waller (1852) that regeneration occurs by fibers growing out from the central stump into the peripheral segment of the nerve, was formulated at a time when the relationship of nerve fibers to nerve cells was not so fully recognized as it is at present; and the Wallerian doctrine may be accepted with confidence today. It has, however, been questioned from time to time, and the earliest to hold an opposite view was Vulpian. Vulpian, working with Philippeaux, cut nerves in young animals, excising long portions so as to prevent the two ends uniting. Some months later they were surprised to find that a number of new perfectly formed nerve fibers had appeared in

the peripheral segment, and that this segment possessed the physiological properties of being excitable and capable of conducting nerve impulses. To this phenomenon they gave the name of "autogenetic regeneration." The publication of these results provoked a long controversy, which lasted from 1859 to 1874, and was closed at the latter day by Vulpian withdrawing his new idea. He did so because in the meanwhile he had repeated his experiments more carefully, and so discovered that, although the ends of the divided nerve had not joined up, connection with the central nervous system had nevertheless been re-established by means of fibers growing into the peripheral segment from other nerves cut through in skin and muscle in the course of operation.

The controversy has been revived within the last few years, and the position of the disputants has been almost exactly the same as that occupied by Waller and Vulpian half a century ago. Modern investigators have, however, the advantage of being able to apply new methods of research, and are provided with many histological reagents of which the older workers were destitute. It is, however, never safe to argue entirely from microscopic appearances, for nerve fibers may be stimulated by non-nervous structures, and a strand that looks like a nerve fiber is not really such unless it can be experimentally shown to be both excitable and capable of conducting nerve impulses.

But none of these investigators have excluded the fallacy which underlay the work of Vulpian and Philippeaux, as has been recently pointed out by Langley and Anderson. These two workers at first thought they also had obtained evidence of purely peripheral regeneration, and it was not until they carried out care-

ful dissections that they convinced themselves that union with the central nervous system had really occurred. The new nerve fibers which grow into the peripheral segment from other nerves, divided in the operation, often do so by a devious and contorted course.

It is possible entirely to prevent reunion with the central ends of divided nerves. This is accomplished by removing a long stretch of the main nerve experimented with, by making the skin incision as small as possible, and by inclosing the top end of the peripheral segment in a cap of sterilized gutta-percha. Under such circumstances no auto-regeneration occurs.

Pieces of nerve may be transplanted under the skin, and in time a few fully formed medullated fibers appear within the degenerated bundle of fibers. This is adduced by Kennedy as undoubted evidence of autogenesis, but, again, is easily explicable on the hypothesis that the new fibers had wandered in from cutaneous nerves divided in the course of the operation, and it was shown that if this fallacy is excluded by transplanting the nerve, not into the subcutaneous tissues, but on to the stomach wall in a sheath of peritoneum, where invasion by nerves is practically impossible, no regeneration occurs at all.

An experiment on somewhat the same lines has been carried out recently by Lugaro; he has shown that regeneration of the cut nerves connected with the lower part of the spinal cord does not occur after that part of the spinal cord has been extirpated. This is a very striking piece of evidence, showing the dependence of the growth of fibers on the activity of the cells of the central nervous system with which they are originally connected.

The first experiments on the functions of the spinal

nerve roots were performed in this country by Sir Charles Bell (1811) and in France by Magendie (1822). These observers found that on section of the anterior roots there resulted paralysis of the muscles supplied by the nerves; on section of the posterior roots there was loss of sensation. These experiments clearly pointed to the conclusion that the anterior roots contain the efferent (motor) fibers; and the posterior roots the afferent (sensory) fibers. This conclusion was confirmed by the experiment of stimulation. Stimulation of the peripheral end of the cut anterior root caused muscular movement; of the central end, no effect. Stimulation of the central end of the cut posterior root caused pain and reflex movements; of the peripheral end, no effect.

These facts of degeneration teach us what we also learn from the study of embryology, that the nerve fibers of the anterior root are connected to the nerve cells within the spinal cord, while the posterior root fibers are connected to the cells of the spinal ganglia; or, to put it another way, the trophic centers which control the nutrition of the fibers are situated within the cord for the anterior roots, and within the spinal ganglia for the posterior roots.

When a nerve is stimulated, the change produced in it is called a nervous impulse; this change travels along the nerve, and the propagation of some change is evident from the effects which follow: sensation, movement, secretion, etc.; but in the nerve itself very little change can be detected. There is no change in form; the most delicate thermopile has failed to detect any production of heat, and we are almost completely ignorant of any chemical changes. We will later show how direct and reflex action of these nerves affect the

vaso-motor nervous system, either by a direct stimulation to the blood vessels, or by accelerating the electro-chemical action of the tissue cells, thereby causing a thermic effect which always accompanies any changes in a nervous impulse and which can be detected in the tissue area directly surrounding the nerve, or its termination. (See chapter on Cells.) The only alteration which can readily be detected as evidence of this molecular change in a nerve is the electrical one. Healthy nerve is iso-electric, but during the passage of a nervous impulse along it there is a very rapid diphasic variation, which travels at the same rate as the nervous impulse. This is similar to the diphasic change in muscle, and can be detected and measured in the same way.

Waller regards the current of action of any excitable tissue as an index of the magnitude of action, and records the movement of the galvanometer by photographing the excursion of the spot of light on a moving photographic plate. He has in this way obtained records from muscle, nerve, retina, skin, plant tissues, etc. He points out that the only available index of action *within the nerve itself* is the electrical sign of activity, whereas in muscle the mechanical action can be compared with its accompanying electrical changes. The amount of contraction in a muscle caused by excitation of its nerve is only a very rough, or even a fallacious indication of the excitability of the nerve, because the nerve is connected to the muscle by motor end-plates, and these, as we have already seen, are fatigued long before the nerve shows any signs of fatigue.

Using this method, Waller has obtained a number of interesting results on the variation in nerve action produced by drugs and other agents. He finds that the

effect of carbonic acid is to cause a diminution, and finally disappearance of the galvanometric response; when this gas is replaced by air the nerve recovers, and the action-currents increase. Ether acts similarly; but with chloroform recovery is difficult to obtain. Small doses of carbonic acid increase the action-currents, and Waller considers that the staircase effect in muscle, and the similar progressive increase noted in the action-currents of nerve as the result of repeated stimulation, are due to the evolution of this gas during activity.

This hypothesis has been recently confirmed by Baeyer and Frohlich. They have shown that peripheral nerves participate in respiratory exchanges, using up oxygen and producing carbonic acid in measurable amounts. In the absence of oxygen, stimulation ceases after some hours to evoke the activity of a nerve, but on readmission of the gas, recovery is almost instantaneous. The store of oxygen so obtained will again keep up nervous activity for a considerable time even although no fresh oxygen is supplied. This illustrates the great power nerve has in repairing itself and in storing oxygen.

There can be no doubt that the existence of the electrical variation is as a rule the index of the excitatory alteration in a nerve. But in the present state of our knowledge we are not justified in assuming that it gives an absolutely faithful record. The electrical variation can be detected in a nerve for many days after its removal from the body; although the electrical change is a concomitant of the real excitatory process, the former may be therefore perceptible when other evidence of the existence of the latter fails. Moreover, Gotch and Buch have obtained further evidence of the dissociation of the electrical response from the excitatory

process. In the frog's sciatic nerve, it is possible with two stimuli in rapid succession to obtain only one electrical response near the seat of excitation which has been cooled, while two such responses occur in a more peripheral warmer region.

Excitability and Conductivity. It is necessary to distinguish between these two properties of nerves. Changes in excitability, and in the power of conducting nerve impulses, do not necessarily go together, as shown in the following experiment: The nerve of a frog's leg is led through a glass tube, the ends of which are sealed with clay, care being taken that the nerve is not compressed. The tube is provided with an inlet and outlet, so that gases may be passed through it. Two pairs of electrodes are arranged, so that the nerve can be stimulated either within or outside the little gas chamber. If carbon dioxide or ether vapor is passed through the tube, both excitability and conductivity are in time abolished, but excitability disappears first; at this stage, if the nerve is stimulated by an induction shock inside the tube, the muscle does not respond, but on stimulating the nerve at the end distant from the muscle and outside the tube, the muscle contracts. The nerve, therefore, is not excitable, though it will conduct impulses. At a later stage shocks administered by either pair of electrodes provoke no contraction. When the poisonous vapor is replaced by air, the nerve recovers, and conductivity returns before excitability. If alcohol vapor is used, conductivity is stated to vanish before excitability.

Gotch has shown *that cold applied to a nerve acts very much like carbonic acid. Intense cold will cause disappearance of both excitability and conductivity;* but cold of such *a degree which abolishes the excita-*

bility of the nerve to induction shocks, increases its excitability to the constant current, and also to mechanical and thermal stimuli.

Dr. R. Kennedy has recently carried out a very careful piece of work on the question of nerve-crossing. He cut in a dog's thigh the nerves supplying the flexor and the extensor muscles, and sutured them together crosswise. Regeneration of structure and restoration of function occurred equally as quick as in those cases in which the central ends had been united to the peripheral ends of their own proper nerves. On examining the cortex of the brain in those animals in which nerve-crossing had been accomplished, it was found that stimulation of the region which in a normal animal gave flexion, now gave extension of the limb, and vice versa.

A series of equally important experiments have also been carried out by Langley, in which he shows that the same facts are true for the nerves that supply involuntary muscle. These nerve fibers will under certain experimental conditions terminate by arborizing around other nerve cells than those which they normally form connections (synapses) with. It will be sufficient to give one typical experiment. *If the vagus nerve is cut across in the neck, its peripheral end degenerates downwards; if the cervical sympathetic is cut across below the superior cervical ganglion, its peripheral end degenerates upwards, as far as the ganglion.* If subsequently the central end of the cut vagus is united to the peripheral end of the cut sympathetic, in the course of some weeks the vagus fibers grow into the sympathetic and form synapses around the cells of the superior cervical ganglion, and stimulation of the united nerve now produces such effects as are usually obtained when the cervical sympathetic is irritated; for

instance, dilation of the pupil, raising of the upper eyelid, and constriction of blood vessels of the head and neck.

Such experiments as these are important *because they teach us that though the action of nerves may be so different in different cases (some being motor, some inhibitory, some secretory, some sensory, etc.) after all what occurs in the nerve trunk itself is always the same; the difference of action is due to difference either in the origin or distribution of the nerve fibers.* If we remember the familiar illustration in which nerve trunks are compared to telegraph wires, we may be helped in realizing this. The destination of a certain group of telegraph wires may be altered, and the alteration may produce different consequences at different places; the electric change, however, in the wires would be the same in all cases. So the nerve impulse going along a nerve is always the same sort of molecular disturbance; if it is made as in the experiment just described, to go by a wrong channel, it produces just the same results as though the impulse had reached its destination by the usual channel.

With our new knowledge of radio-activity and radio-circuits some new startling facts can be drawn from the presence and construction of synapses in the nervous system, which will be taken up later. (See chapter on Synapses.)

What is the nature of this change which we have provisionally been alluding to as a molecular disturbance? The theories fall under two main headings—chemical and physical. In a chemical theory we may compare the transmission of the impulse to the propagation of a flame along a train of gunpowder; but *such an analogy is very imperfect,* for the gunpowder is

entirely consumed, and has not the power to repair itself as a nerve has. Nevertheless, there are certain facts which make a chemical theory acceptable; these are:

(1) Analogy with muscle, where the propagation of the muscular impulse is undoubtedly largely due to the propagation of chemical disturbances.

(2) Evidence that the nerve does undergo metabolic changes, as shown by the necessity of oxygen, and the production of minute amounts of carbon dioxide.

(3) Arrhenius and van't Hoff showed that a rise of 10° in temperature increases the velocity of a chemical reaction to two or three times its original rate. Purely physical changes are not accelerated nearly so greatly by the same rise of temperature. Maxwell's recent experiments show that a rise of 10° C. approximately doubles the velocity of nerve conduction, and the conclusion is drawn that, therefore, the nerve impulse is a chemical phenomenon. Keith Lucas confirmed this observation. Woolley obtained the same figure from the influence of temperature on the rate of conduction in muscle, so probably the conduction process is of a similar nature in both tissues. (See chapter on Electro-Chemistry of Proteins.)

The physical theories in relation to this question compare the nerve impulse to the way in which an electrical change is propagated along a wire. When the electrical accompaniment of nervous activity was first discovered this view was unhesitatingly accepted by many physiologists, and the current of action was regarded not as an accidental concomitant of the impulse, but as the change which really constitutes the essence of the impulse, *and which serves to excite the chemical and other changes in the tissues to which the nerve is distributed.* Two facts, however, stood out at

once which rendered the adoption of this simple view difficult; one of these is the slow rate of conduction in nerve; and the other is the phenomenon of inhibition; it is quite conceivable that an electrical disturbance, feeble though it be, can fire off an excitable tissue and lead to increase in its activity; it is much more difficult to understand how it can possibly produce a lessening of action such as occurs in inhibition. *Nevertheless, the "discharge hypothesis," as it used to be called, has been revived of late in modified form, and electrolytic changes with liberation of ions occurring between the fibrils and the interfibrillar material are supposed to constitute the main feature of the impulse.* Macdonald considers that the potassium salts in organic combination within the axis-cylinder are the principal materials that undergo the change which is propagated along the nerve; he thus reduces the phenomenon of nervous conduction to *electrolytic dissociation and association of inorganic ions.* The comparatively slow rate at which the change is propagated must, if this is so, be due to admixture or combination of the salt with the less mobile colloid substances of the conducting core. It is interesting to state, if only in outline, the kind of theories which are in the air at present. *A thorough research in Electro-Chemistry of Proteins, however, leaves no doubt as to the validity of this theory, and further knowledge of the latest findings on the actions of electrons make this an acceptable working basis; especially so if experiments conducted to determine this have proven to be correct.*

The latest discovery of electronic energy, the nature of the atom, its relation or rather dependence upon the presence of electrons, to form it, and hold it in molecular combination seem to give ample explanation for the

chemical changes (atomic-changes) which nerve impulses cause. All of these earlier experiments were made when this knowledge was not available or, at least, as extensive as it is today. It is, however, with the knowledge of these experiments that we are enabled today to more fully understand this subject in the light of the modern electronic conception.

The proportion of mineral salts amounts to a little more than 1 per cent of the total solids. Potassium salts are the most abundant. We have already noted that Macdonald attributes many of the phenomena of nervous action to electrolytic changes in these potassium salts.

When the nutrition of the nerves is impaired much stronger currents of both the induced and constant kinds are necessary to evoke muscular contractions than in the normal state. When the nerves are completely degenerated (as, for instance, when they are cut off from the spinal cord, or when the cells in the cord from which they originate are themselves degenerated, as in infantile paralysis) no muscular contraction can be obtained on stimulating the nerves even with the strongest currents.

The changes in the excitability of the muscles are less simple, because in them there are two excitable structures, the terminations of the nerves, and the muscular fibers themselves. Of these, the nerve fibers are the more sensitive to induction currents, and the faradic stimulation of a muscle under normal circumstances is by means of these motor nerve endings. Thus we find that its excitability corresponds in degree to that of the motor nerve supplying it. The muscular fibers are, even in the normal state, less sensitive to faradism (that is, a succession of induction shocks) than the nerve,

because they are incapable of ready response to stimuli so very short in duration as are the shocks of which a faradic current consists. The proof of this consists in the fact that under the influence of curare, which renders the muscle practically nerveless, the muscle requires a much stronger faradic current to stimulate it than in the normal state. When the nerve is degenerated, the make or break of the constant current stimulates the muscle as readily as in the normal state; but the contraction is propagated more slowly than that which occurs when the nerve fibers are intact, and is due to the stimulation of the muscular fibers themselves. The fact that, under normal circumstances, the contraction which is caused by the constant current is as quick as that produced by an induction shock, is ground for believing that in health the constant, like the induced current, causes the muscle to contract chiefly by exciting the motor nerves within it. *When the motor nerve is degenerated, and will not respond to any form of electrical stimulation, the muscle also loses all its power of response to induction shocks. The nerve degeneration is accompanied by changes in the nutrition of the muscular fibers, as is evidenced by their rapid wasting, and any power of response to faradism they possessed in the normal state, is lost. But the response of the muscle to the constant current remains,* and is indeed more ready than in health, doubtless in consequence of nutritive changes, i. e., electro-chemical changes. There is, moreover, a qualitative as well as a quantitative change. In health the first contraction to occur upon gradually increasing the strength of the current is at the negative pole, when the circuit is closed; and a stronger current is required before closure-contraction occurs at the positive pole. But in the morbid state we are discussing,

closure-contraction may occur at the positive pole as readily as at the negative pole. This condition is called the "Reaction of Degeneration."

The whole nervous system consists of nerve cells and their branches, supported by neuroglia in the central nervous system, and by connective tissue in the nerves. Some of the processes of a nerve cell break up almost immediately into smaller branches ending in arborescences of fine twigs; these branches, which used to be called protoplasmic processes, are now termed dendrons. One branch becomes the long axis-cylinder of a nerve fiber, but it also ultimately terminates in an arborization; it is called the axis-cylinder process, or, more briefly, the axon. The term neuron or neurone is applied to the complete nerve unit, that is, the body of the cell, and all its branches. The fibrils of the axon may be traced through the body of the cell from the dendrons.

The next idea which it is necessary to grasp is, that each nerve unit (cell plus branches of both kinds) is anatomically independent of every other nerve unit. *There is no true anastomosis of the branches from one nerve cell with those of another; the arborizations interlace and intermingle, and nerve impulses are transmitted from one nerve unit to another, through contiguous, but not through continuous structures.* A convenient expression for the intermingling of arborizations is *synapse* (literally, a clasping).

Excitation occurs at the skin or other sensory surface, and the impulse is transmitted by the sensory nerve-fiber to the central nervous system. It does not become anatomically connected to any of the cells of the central nervous system. The only cell body in actual continuity with the sensory nerve fiber is the one in the spinal

ganglion from which it grew. On entering the spinal cord, the main fiber conveys impulses upwards which ultimately reach the brain, but in the spinal cord it gives off fine side branches or collaterals which terminate in branches that arborize around one or more cell bodies and their dendrons; these cells are small ones situated in the posterior cornu of the spinal gray matter. This short axon of this cell similarly terminates by a synaptic junction with one or more of the large multipolar cells of the anterior cornu of the spinal gray matter. This motor cell is thus stirred up to action and sends an impulse by its axon to the muscular fibers it supplies. Thus excitation of the skin will cause, by this spinal reflex arc, the contraction of muscles. In some cases severe excitation will cause contraction of the muscles of the opposite side of the body (crossed reflex); under such circumstances the intermediary neuron sends its axon to the anterior horn cells of the opposite side. The synaptic junctions are naturally the places which the impulse has the greatest difficulty in traversing, and some observers believe that at the points of contact there is a kind of undifferentiated interstitial protoplasm which the impulse has to get through. (See chapter on Synapses.)

This example illustrates a most important general truth, namely, that a nervous impulse does not necessarily travel along the same nerve fiber all the way, but there is what we may term a system of relays.

An illustration of this follows: Suppose one wishes to move the arm; the impulse starts in the nerve cells of the brain, but there are no fibers that go straight from the brain to the muscles of the arm. The impulse travels down the spinal cord, by what are called pyramidal fibers, which form synapses with the nerve cells of the

spinal cord, and from these cells fresh nerve fibers pass on the impulse to the arm muscles. The cell of the cerebral gray matter and its axon (pyramidal fiber) passes into the white matter of the brain, and in the medulla oblongata it crosses over and then travels down the opposite side of the spinal cord. It enters the gray matter in the part of the cord which controls the arm movements, and terminates by arborizing around small cells at the base of the posterior cornu; thence the impulse is transferred to the large motor cells of the anterior cornu and the final link in the chain is formed by the motor nerve fibers to the muscular fibers. The spinal cord cells are thus surrounded by arborizations (synapses), derived not only from the sensory nerves but by fibers from the upper part of the nervous system. We now see how it is possible that reflex actions in the cord may be controlled by impulses from the brain.

The system of relays is still more complicated in the case of sensory impulses, as we shall see later on; the same is true for the motor path to involuntary muscle, accessory cell stations being situated in the sympathetic ganglia. If the nerve fiber is cut off from its connection with the spinal nerve cell, the peripheral end degenerates as far as the muscle. (References from Halliburton.)

CHAPTER IX

PHYSIOLOGY OF NERVES (SPECIFIC)

THE CENTRAL NERVOUS SYSTEM

THE central nervous system is contained within the cranio-spinal cavity, and consists of brain and spinal cord. These two parts are continuous with one another, and the line of separation is arbitrarily drawn at the foramen magnum, by which orifice the spinal cord leaves the skull. Both brain and cord are enveloped by three connective tissue membranes, known from without inwards as dura mater, arachnoid, and pia mater, respectively.

THE NERVOUS FACTOR IN RESPIRATION

In the central nervous system there is a specialized small district called the respiratory center. This gives out impulses which travel down the spinal cord to the centers of the spinal nerves that innervate the muscles of respiration. It also receives various afferent fibers, the most important of which are contained in the trunk of the vagus. The vagus is chiefly an afferent nerve in relation to respiration. It, however, also is in a minor degree efferent, for it supplies the muscular tissue of the lungs and bronchial tubes, and exercises a trophic influence on the lung.

The respiratory center was discovered by Flourens; it is situated at the tip of the calamus scriptorius, and coincides in position with the sensory center of the vagus. The existence of subsidiary respiratory centers in the spinal cord has been mooted, but the balance of

experimental evidence is against their existence. *Flourens found that when the respiratory center is destroyed, respiration at once ceases, and the animal dies.* He therefore called it the "vital knot" (noeud vitale). THIS IS ONE OF THE MOST VITAL FACTS TO PROVE THE ELECTRO-CHEMICAL ACTION, OF ALL BODILY FUNCTION, SINCE EVERY NERVE IMPULSE CAUSING CHEMICAL CHANGES INDIRECTLY CAN ONLY CONTINUE TO ACT AS LONG AS THE RESPIRATORY FUNCTION SUPPLIES THE BODY WITH NEW OXYGEN AND ITS ELECTRON COMPONENT.

The center is affected not only by the afferent impulses which reach it by such nerves as the vagus, but also by those from the cerebrum; so that we have a limited amount of voluntary control over the respiratory movements.

The respiratory center is probably twofold, consisting of an inspiratory and an expiratory center. Of these two the inspiratory center is so much the more active that its importance is a subject of universal agreement; whereas, the existence of an expiratory center is doubted by some physiologists, who regard expiration as a mere cessation of the active process of inspiration, and a mechanical falling back of the tissues into their places.

During normal respiration, as opposed to forced respiration, an impulse passes from the lung to the respiratory center during each complete respiration. *This has been discovered by placing the vagus on non-polarizable electrodes connected to a galvanometer, and observing the current of action which accompanies*

each impulse. The action-current takes place at the height of each inspiration.

The currents that occur in the vagus during respiration can be studied with the capillary electrometer, as was done by Alcock and Seemann; they can still be more accurately studied by the use of Einthoven's string galvanometer.

A theoretical question arises at this point: supposing no inhibitory impulse came up the vagus, would the inspiration ever cease of itself? In answer to this question we may say at once that when both vagi are divided, the respirations become much slower and deeper but they do not entirely cease. If this were the whole case, we should conclude that the respiratory center had a slow inherent rhythm, which was quickened by the vagus impulses; but it is claimed that when all impulses, both from the brain above and the sensory nerves below, are cut off from the respiratory center, the respiratory rhythm ceases.

There are in the vagus two sets of fibers, one of which produces an increased activity of the inspiratory part of the respiratory center, and the other an increased activity of the expiratory part of that center. Stimulation of the first stops expiration and produces inspiration; stimulation of the second does the reverse.

In connection with the relative importance of the nervous and chemical factors in breathing, F. H. Scott has shown that the principal respiratory nerves (the pneumogastrics) regulate the rate of rhythm of the respiratory movements, whilst the chemical factor specially regulates the amount of pulmonary ventilation, that is, the depth of the individual respiratory efforts; for when these nerves are divided, a rise in the alveolar tension of carbon dioxide (or great diminution of the

oxygen in the respired air) increases the depth, but not the rate of breathing.

To recapitulate: In a normal respiration the chemical and nervous factors would, therefore, appear to be related somewhat as follows: The inspiratory center makes an effort, the degree of exaltation of the center, and, therefore, the magnitude of the effort, more especially in the matter of depth, is governed by the tension of carbonic acid in the blood, but it is cut short by an inhibitory impulse passing up the vagus, only to begin again when the effects of this inhibitory impulse are removed.

During fœtal life the need of the embryo for oxygen is small, and is amply met by the transference of oxygen from the maternal blood through the thin walls of the fœtal capillaries in the placenta. But when the child is born, this source of oxygen is no longer available, and the increasing venosity of the blood stimulates the respiratory center to action, and is the essential cause of the first inspiratory efforts the new-born child makes to obtain the oxygen it requires. It is said that if the placental circulation is stopped while the child is still in utero, respiratory efforts are also made. Some regard the action of the air on the body surface as an accessory cause of the first respirations, and it is the practice to increase this in feeble children by stimulating the cutaneous nerves by the application of cold water to the skin. Such treatment always causes deep inspirations, even in the adult. There are other nerves stimulation of which influences the respiratory act; for instance, stimulation of the central end of the glossopharyngeal inhibits the respiratory movement for a short period, this accounts for the very necessary cessation of breathing during swallowing. Stimulation of

the central end of the cut superior laryngeal nerve, or of its termination in the mucous membrane of the larynx, as when a crumb is swallowed the wrong way, produces an increase of respiratory efforts, culminating in coughing. The reader will find great inspiration and enlightenment after a study of Book II, Calvin Samuel Page's discoveries, relating to Oxygen and respiration.

VASO-MOTOR SYSTEM

The vaso-motor nervous system consists of the vaso-motor center situated in the bulb, of certain subsidiary vaso-motor centers in the spinal cord and of vaso-motor nerves, which are of two kinds: (a) those the stimulation of which causes constriction of the vessels; these are called vaso-constrictor nerves; (b) those the stimulation of which cause dilatation of the vessels; these are called vaso-dilator nerves.

The muscular structure of arteries was first described by Henle in 1841; but it was not until twelve years later that the nerves supplying this muscular tissue were discovered. The names of Claude Bernard, Brown-Sequard, and Schiff are specially connected with this discovery.

These nerves exert their most important action in the vessels which contain relatively the greatest amount of muscular tissue, namely, the small arteries or arterioles.

Under ordinary circumstances the arterioles are maintained in a state of moderate or tonic contraction, and this constitutes the peripheral resistance, the use of which is to keep up the arterial pressure, which must be high enough to force the blood through the capillaries and veins in a continuous stream back to the heart.

Another function which is served by this muscular tissue is to regulate the amount of blood which flows

through the capillaries of any organ in proportion to its needs. During digestion, for instance, it is necessary that the digestive organs be supplied with a large quantity of blood; for this purpose the arterioles of the splanchnic area are relaxed, and there is a vast amount of blood in this area, and therefore a correspondingly small amount in other areas, such as the skin; this accounts for the sensation of chilliness experienced after a full meal. And it is a fact that the areas directly surrounding or over the spinal nerves, supplying the digestive organs, show a marked increase in temperature during the period of digestion. The skin vessels form another good example; one of the most important uses of the skin is to get rid of the heat of the body in such a way that the body temperature shall remain constant; *when excess of heat is produced* there is also an *increase in the loss of heat;* the skin vessels are then dilated, and so more blood is exposed on the surface, and thus an increase in the radiation of heat from the surface is brought about. On the other hand, when it is necessary that the heat produced should be kept in the body, the loss of heat is diminished by a constriction of the skin vessels, as in cold weather. The alteration of the caliber of the vessels is brought about by the action of the vaso-motor nervous system on the muscular tissue of the arterioles.

There are certain organs of the body in which the necessity for alterations in their blood supply does not exist. Such organs are, the heart, the lungs and the brain. It is through the vessels of these organs that the influence of vaso-motor nerves is at a minimum. The pulmonary vessels are stated by Bradford and Dean to be supplied by nerves which leave the cord in the upper thoracic region; but on stimulating these the rise of

pressure produced is extremely small. It is very doubtful if the fibers in question are really vaso-constrictors; the small rise observed may be partly or even wholly due to the acceleration of the heart, which is another result of stimulating these nerve roots.

The vaso-motor center lies in the gray matter of the floor of the fourth ventricle; it is a few millimeters in length, reaching from the upper part of the floor to within about 4 mm. of the calamus sciptorius. The position of this center has been discovered by the following means: When it is destroyed the tone of the small vessels is no longer kept up, and in consequence there is a great and universal fall in arterial blood pressure; when it is stimulated there is an increase in the constriction of the arterioles all over the body, and therefore a rise of arterial blood pressure. Its upper and lower limits have been determined in the following way: A series of animals are taken, and the central nervous system divided in a different place in each; the cerebrum and cerebellum may be cut off without effecting blood pressure, the vaso-motor center must therefore be below these. If the section is made just above the medulla, the blood pressure still remains high, and it is not till the upper limit of the center is passed that the blood pressure falls. Similarly, in another series of animals, if the cervical cord is cut through, and the animal kept alive by artificial respiration, there is an enormous fall of pressure due to the influence of the center being removed from the vessels. In other experiments the section is made higher and higher, and the same result noted, until at last the lower limit of the center is passed, and the fall of pressure is less and less marked the higher one goes there, until in the animal in which the section is made at the upper boundary

of the center the blood pressure is not affected at all, and the center can be influenced reflexly by the stimulation of afferent nerves, the pressor and depressor nerves.

After the destruction of the vaso-motor center in the bulb, there is a fall of pressure. If the animal is kept alive, the vessels after a time recover their tone, and the arterial pressure rises; it rises still more on stimulating the central end of a sensory nerve. This is due to the existence of subsidiary vaso-motor centers in the spinal cord, for on the subsequent destruction of the spinal cord the vessels again lose their tone and the blood pressure sinks.

The vaso-constrictor nerves for the whole body leave the spinal cord by the anterior roots of the spinal nerves from the second thoracic to the second lumbar, both inclusive. They leave the roots by the white rami communicantes, and pass into the ganglia of the sympathetic chain, which lies on each side of the vertebral column. That is to say, the small medullated or pre-ganglionic nerve fibers terminate by arborizing around the cells of these ganglia, and a fresh relay of axis-cylinder processes from these cells carry on the impulses.

Those which are destined for the supply of the vessels of the head pass into the ganglion stellatum or first thoracic ganglion, thence through the annulus of Vieussens to the inferior cervical ganglion, and thence along the sympathetic trunk to their destination. Their cell station is in the superior cervical ganglion.

The new fibers that arise in ganglia are usually non-medullated and are termed post-ganglionic. Those for the body wall and limbs pass back from the sympathetic ganglia to the spinal nerves by the gray rami communicantes, and are distributed with the other spinal nerve

fibers. The cell stations for the upper limb fibers are in the ganglion stellatum, and for the lower limb fibers in the lower lumbar and upper sacral ganglia.

Those for the interior of the body pass into the various plexuses of sympathetic nerves in the thorax and abdomen, and are distributed to the vessels of the thoracic and abdominal viscera. This set includes the most important vaso-motor nerves of the body, the splanchnics. Their cell stations are situated in the various collateral ganglia.

The vaso-dilator nerves have been stated to accompany those just described, but they are not limited to the outflow from the second thoracic to the second lumbar. Thus, the nervi erigentes originate as white rami communicantes from the second and third sacral nerves, and the chorda tympani; another good example of a vaso-dilator nerve, is a branch of the seventh cranial nerve.

Our knowledge of vaso-dilator nerves is limited, except in such instances as the two nerves just mentioned. Equally deficient is our information concerning vaso-dilator centers in the central nervous system. Not only is vaso-dilatation the result of mechanical or electrical stimulation of these roots, but experiments are adduced which show that in normal reflexes, such as occur when the depressor nerve is stimulated, the dilator impulses travel by the same route. This raises the question whether the posterior roots contain true efferent fibers. The facts of degeneration show that they do not. Bayliss is therefore driven to the conclusion that the same nerve terminations in the periphery serve both to take up sensory impressions and to convey inhibitory impulses to the muscular structures in which they end. In other words, we have here another example which may be

added to those previously mentioned, that nerve fibers may convey impulses in both directions.

The vaso-motor center can be excited directly by induction currents; the result is an increase of arterial blood pressure owing to an increase of the contraction of the peripheral arterioles.

The vaso-motor center may be excited reflexly. The afferent impulses to the vaso-motor center may be divided into pressor and depressor.

Most sensory nerves are pressor nerves. The sciatic or the vagus nerves may be taken as instances. When they are divided and their central ends stimulated, the result is a rise of blood pressure due to the stimulation of the vaso-motor center, and a consequent constriction of the arterioles all over the body, but especially in the splanchnic area.

Many sensory nerves also contain depressor fibers; these produce the opposite effect. The most marked bundle of these is known as the depressor nerve. In most animals this is bound up in the trunk of the vagus, but in some, such as the rabbit, cat and horse, the nerve runs up as a separate branch from the heart (or, according to some recent observations, from the commencement of the aorta), and joins the vagus or its superior laryngeal branch and ultimately reaches the vaso-motor center. When this nerve is stimulated (the vagi having been previously divided to prevent reflex inhibition of the heart), a marked fall of arterial blood pressure is produced. Stimulation of this nerve affects the vaso-motor center in such a way that the normal constrictor impulses that pass down the vaso-constrictor nerves are inhibited. The fall of pressure is very slight after section of the splanchnic nerves, showing that the splanchnic area is the part of the body most affected.

The normal function of this nerve is to adapt the peripheral resistance to the heart's action; if the constriction of the arterioles is too high for the heart to overcome, an impulse by this nerve to the vaso-motor center produces reflexly a lessening of the peripheral resistance.

The term depressor should be carefully distinguished from inhibitory. Stimulation of the peripheral end of the vagus produces a fall of blood pressure due to inhibition (slowing or stoppage) of the heart; stimulation of the central end of the depressor nerve produces a lowering of blood pressure for a different reason, namely, a reflex relaxation of the splanchnic arterioles.

The vaso-motor nervous system is influenced to some extent by conditions of the cerebrum, some emotions, such as fear, causing pallor (vaso-constriction), and others causing blushing (vaso-dilatation).

It is almost impossible to over-estimate the importance of the study of vaso-motor phenomena as a means of explaining certain pathological conditions. Our knowledge of the processes concerned in inflammation is a case in point.

Disorders of the vessels due to vaso-motor disturbances are generally called angio-neuroses. Of these we may mention the following:

Tache cerebrale is due to abnormal sensitiveness of the vascular nerves; drawing the finger-nail across the skin causes an immediate wheal, or at least a red mark that lasts a considerable time. At one time this was considered characteristic of affections of the cerebral meninges such as tubercular meningitis, and was consequently called the "meningeal streak." It, however, occurs in a variety of pathological conditions of the nervous system, both cerebral and spinal. In certain

conditions which lead to angina pectoris the pain in the heart is in part due to its being unable to overcome an immense peripheral resistance.

Raynaud's disease is one in which there is a localized constriction of the vessels which is so effectual as to entirely cut off the blood supply to the capillary areas beyond, and if this lasts any considerable time may lead to gangrene of the parts in question.

INNERVATION OF THE HEART

The nerves of the heart, which under normal circumstances control its movements are:

1. Cardiac branches of the vagus (inhibitory fibers).
2. Cardiac branches of the sympathetic (augmentor and accelerator fibers).

These pass to the heart and terminate in certain collections of ganglion cells in its walls; from these cells fresh fibers are distributed among the muscular fibers. In addition to these nerves, which are efferent, we have to mention:

3. The sensory or afferent nerves of the heart, the best known of which is called the *depressor* nerve. This nerve, starting from the cardiac tissue, joins the vagus trunk; it passes to the bulb, especially to the vaso-motor center. We shall therefore postpone its study until we are considering the vaso-motor nerves.

The Vagus. The ninth, tenth and eleventh cranial nerves arise close together from the gray matter in the floor of the fourth ventricle, and leave the bulb by a number of rootlets. These rootlets are divided by Grossman into three groups, a, b, and c; there is a good deal of blending of the rootlets before they ultimately emerge from the skull, but there a group corresponds fairly well with the fibers of the glosso-pharyngeal, b

with those of the vague, and c with those of the spinal accessory. The rootlets of the tenth nerve pass through two ganglia called respectively the *jugular ganglion,* and the *ganglion trunci vagi.* The fibers of the spinal accessory nerve which join the vagus are chiefly motor, especially to the larynx, but some go to the heart. The vagus gives off branches to many organs, pharynx, larynx, heart, lungs, aesophagus, and various abdominal organs. We have however, in this place only to deal with its cardiac fibers. It has been known since the experiments of the Brothers Weber in 1845 that stimulation of one or both vagi produces slowing or stoppage of the beats of the heart. It has since been shown that in all vertebrate animals, this is the normal result of vagus stimulation; the phenomenon is called *inhibition,* and the nerve fibers *cardio-inhibitory.* Section of one vagus produces slight acceleration of the heart; this result is better marked when both vagi are divided. This shows that the restraining influence of the vagus is being continuously exercised; it is, however, found the amounts of vagus control varies a good deal in different animals. The most potent artificial stimulus which can be applied to the vagus nerve to produce inhibition of the heart is a rapidly interrupted induction current; severe mechanical stimuli have a slight effect, but chemical and thermal stimuli are ineffective.

A certain amount of confusion has arisen as to the effect of vagus stimulation, because so many experiments have been made on the frog. In this animal the sympathetic fibers join the vagus after it leaves the skull, and so what is usually called the vagus in this animal should more properly be termed the *vago-sympathetic.* It will readily be understood that by stimulating a mixed nerve, one obtains an intermixture

of effects. If, however, one stimulates the intracranial vagus before the sympathetic blends with it, a pure inhibitory effect is obtained. The inhibitory effect is usually manifested first, and this is followed by the augmentor effect due to sympathetic action. But it is by no means infrequent to obtain the phenomena in the reverse order. It is often stated that the right nerve contains more inhibitory fibers than the left, but this is by no means a constant rule. One can always obtain good inhibition if the stimulus is applied to the wall of the sinus; here one stimulates the post-ganglionic fibers which originate from the nerve cells in the sinus ganglion around which the vagi terminate.

The effect of the stimulus is not immediately seen; one or more beats may occur before stoppage of the heart takes place, and slight stimulation may produce only slowing and not complete stoppage of the heart. The stoppage may be due either to prolongation of the diastole, as is usually the case, or to diminution of the sytole. Vagus stimulation lessens the conductivity of the cardiac tissues, but it does not abolish the irritability of the heart muscle, since direct mechanical stimulation may bring out a beat during the standstill caused by vagus stimulation. The inhibition of the beat varies in duration, but if the stimulation is a prolonged one, the beats reappear before the current is shut off. This is known as "vagus escape," and is probably due to fatigue of the vagal endings.

THE SYMPATHETIC

The influence of the sympathetic is the reverse of that of the vagus. Stimulation of the sympathetic produces acceleration of the heart-beats, and as a rule, section of the nerve produces slowing. Hence, the nerve

is also in constant action like the vagus. The acceleration produced by stimulation of the sympathetic fibers is accompanied by increased force, and so the action of the nerve is also termed *augmentor*. It is probable that the augmentor fibers are distinct from the accelerator fibers, because in mammals one or two of the small nerves leaving the stellate ganglion on stimulation produce augmentation without acceleration.

The fibers of the sympathetic system which influence the heart-beat in the frog, leave the spinal cord by the anterior root of the third spinal nerve, and pass by the ramus communicans to the third sympathetic ganglion, then to the second sympathetic ganglion, then by the annulus of Vieussens (round the subclavian) to the first sympathetic ganglion, and finally in the main trunk of the sympathetic, to near the exit of the vagus from the cranium, where it joins that nerve and runs down to the heart within its sheath, forming the joint vago-sympathetic trunk. The fibers of the sympathetic running up into the skull are for the supply of blood vessels there. It should be noted that the frog has no spinal accessory nerve.

In the mammal the sympathetic fibers leave the cord by the second and third dorsal nerves, and possibly by an anterior root of two or more lower nerves; they pass by the rami communicantes to the ganglion stellatum, or first thoracic ganglion, and thence by the annulus of Vieussens to the inferior cervical ganglion of the sympathetic; fibers from the annulus, or from the inferior cervical ganglion, proceed to the heart.

In man, the cardiac branches of the sympathetic travel to the heart from the annulus of Vieussens and cervical sympathetic in superior middle and lower bundles of fibers. These pass into the cardiac plexus, and

surrounding the coronary vessels ultimately reach the heart.

Note: The inhibitory fibers are medullated, and only measure 2 to 3 U. (=micro-millimeter) in diameter; they pass to the heart and have their cell stations in the ganglia of that organ. Some of the sympathetic fibers, on the other hand, reach the heart as non-medullated fibers, having their cell stations in the sympathetic (inferior cervical and first thoracic) ganglia; but the majority do not reach their cell stations until they reach terminal ganglia in the heart wall. The augmentor and accelerator centers in the central nervous system have not yet been accurately localized.

Influence of Drugs. The question of the action of drugs on the heart forms a large branch of pharmacology. We shall be content here with mentioning two only, as they are largely used for experimental purposes by physiologists. *Atropine* produces considerable augmentation of the heart-beats by paralyzing the inhibitory mechanism. *Muscarine* (obtained from poisonous fungi) produces marked slowing, and in larger doses temporary stoppage of the heart. Its effect is a prolonged inhibition, and can be removed by the action of atropine. The action of atropine cannot, however, be easily antagonized by muscarine; a large dose is necessary. That these drugs act on the nerves, and not the muscular substance of the heart, is shown by the fact that in the hearts of early embryos, so early that no nerves have yet grown to the heart, these drugs have little or no effect. (Pickering.)

Reflex Inhibition. Thus there is no doubt that the vagi nerves are simply the media of an inhibitory or restraining influence over the action of the heart, which

is conveyed through them from the center in the medulla oblongata, which is always in operation. The restraining influence of the center in the medulla may be reflexly *increased* by stimulation of many afferent nerves, particularly those from the nasal mucous membrane, the larynx and the lungs. A blow on the abdomen causes inhibition and fainting; a blow on the larynx, even a moderate one, will kill. There is no comparison between the ease with which stimulation of the laryngeal or pulmonary fibers produces inhibition as compared to the difficulty of obtaining inhibition from the alimentary tract. Tobacco smoke in some people and animals, by acting on the terminations of the vagi or their branches in the respiratory system, may also produce reflex inhibition of the heart. Some very remarkable facts concerning the readiness by which reflex inhibition of the fish's heart may be produced were made out by McWilliam; any irritation of the tail, gills, mucous membrane of mouth and pharynx, or of the parietal peritoneum, causes the heart to stop beating.

In connection with the subject of reflex inhibition, it may be mentioned in conclusion that though we have no voluntary control over the heart's movements yet cerebral excitement will produce an effect on the rate of the heart, as in certain emotional conditions.

THE INFLUENCE OF THE CENTRAL NERVOUS SYSTEM ON HEAT REGULATIONS

The central nervous system controls the loss of heat directly through vaso-motor and secretory nerves supplying the skin. That the control of heat production is important, is shown by the effect on the body temperature of cutting the spinal cord, or of the drug

curare. Curare cuts off the muscles from the stimuli which would naturally reach them through the motor nerves. Not only does the temperature at once fall, but the animal becomes poikilothermic.

The seat of the heat regulating mechanism in the brain is a matter of much uncertainty. It is possibly in the basal ganglia of the cerebrum, or in this neighborhood.

Fever. Diseases may cause the temperature to vary considerably, especially those which we term febrile.

A mere increase in the production of heat does not necessarily cause fever. The administration of food causes increased combustion in the body; but there is no rise of temperature in health, because *parsi passu* with the increased production, there is increased loss of heat. Similarly, diminution in the loss of heat, such as occurs on a hot as compared with a cold day, does not produce fever, because the production of heat within the body is correspondingly diminished. A febrile condition may, however, occur if tight fitting and otherwise unsuitable clothing which interferes with the proper action of the skin is worn in hot weather; this is the frequent cause of "heat-stroke" in the tropics.

In fever there is increased production of heat, as is shown by metabolic balance sheets; the intake of food is usually small, and the discharge of carbon, nitrogen, etc., results mainly from tissue disintegration; this is even greater than in ordinary inanition; the tissues are said to be in a "labile" condition, that is, they are easily broken down. Usually the skin is dry, the sweat glands, like most of the secretory glands, being comparatively inactive, and so the discharge of heat is lessened. The skin, however, may sometimes be bathed in perspiration and yet high fever be present. The

essential cause of the high temperature in fever is increased formation or generation of heat, and an interference with the mechanism which in health operates so as to equalize the two. This subject is treated later in detail.

GLYCOGENOLYTIC NERVES—LIVER

Stimulation of the coeliac plexus leads to a loss of glycogen in the liver, with a corresponding increase of glucose in the blood. The disappearance of glycogen from the liver cells after the stimulation of these nerves can be seen histologically (Cavazzani). This is due to a direct influence of the nerves on the liver cells, for the effect is obtained after the circulation is stopped by ligature of the aorta and portain vein (Morat and Dufourt).

The most recent work on this subject is that of J. R. R. Macleod, who finds that the glycogenolytic fibers, (the action of which is to increase the sugar in the blood at the expense of the hepatic glycogen) are demonstrable with certainty only in the case of the greater splanchnic nerves. If it occurs as the result of vagus stimulation (as Bernard stated), it is due to asphyxia which is produced; if precautions are taken to prevent asphyxia, no increase of blood sugar is found. In asphyxia it is increase of carbonic acid, and not less oxygen, which produces the glycosuric condition, and the former gas probably acts directly on the liver cells themselves.

THE GLYCOGENIC FUNCTION OF THE LIVER

The important fact that the liver normally forms sugar, or a substance readily convertible into it, was discovered by Claude Bernard in the following way:

He fed a dog seven days with food containing a large quantity of sugar and starch; and, as might be expected, found sugar in both the portal and hepatic blood. But when this dog was fed with meat only, to his surprise, sugar was still found in the blood of the hepatic veins. Repeated experiments gave invariably the same result; no sugar was found, under a meat diet, in the portal vein, if care were taken, by applying a ligature on it at the transverse fissure, to prevent reflux of blood from the hepatic venous system. Bernard found sugar also in the substance of the liver. It thus seemed certain that the liver formed sugar, even when from the absence of carbohydrates in the food, none could have been brought directly to it from the stomach or intestines.

Bernard found, subsequently, that a liver, removed from the body, and from which all sugar had been completely washed away by injecting a stream of water through its blood vessels, contained sugar in abundance after the lapse of a few hours. The post-mortem production of sugar was a fact which could only be explained on the supposition that the liver contained a substance readily convertible into sugar; and this theory was proved to be correct by the discovery of a substance in the liver allied to starch, and now termed *glycogen* or animal starch. We are thus led to the conclusion that glycogen is formed first and stored in the liver cells, and that the sugar, when present, is the result of its transformation.

SOURCE OF GLYCOGEN

Although the greatest amount of glycogen is produced by the liver upon a diet of starch and sugar, a certain quantity is produced upon a protein diet. It

must, then, be produced by protoplasmic activity within the cells. The glycogen, when stored in the liver cells, may readily be demonstrated in sections of liver containing it by its reaction (red color) with iodine, and moreover, when the hardened sections are soaked in water to dissolve out the glycogen, the protoplasm of the cell may be so vacuolated as to appear little more than a framework. In the liver of a hibernating frog the amount of glycogen stored up in the cells is very considerable.

THE PITUITARY BODY

This occupies the sella turcica of the sphenoid bone. It may be divided into three parts, which show developmental, structural and functional differences.

(1) The *anterior lobe* is developed as a tubular prolongation from the epiblast of the buccal cavity, but the growth of intervening tissue soon cuts off all connection with the mouth. It consists of large granular cells and numerous blood vessels. Its precise function is undetermined, although probably it is a vascular gland pouring an internal secretion into the blood, which influences growth. Abnormal hypertrophy of the pituitary produces the condition known as *acromegaly,* in which the bones of the face and limbs become hypertrophic; and if the view advanced above of the anterior lobe is correct, the condition is caused by an increase of the internal secretion. Feeding young animals and children in the anterior lobe hastens the growth of their skeletal tissues.

(2) The *pars intermedia.* This lies between the anterior and posterior lobes, and forms a closely fitting investment of the latter lobe. It is developed in association with the anterior lobe, and consists of fine

granular cells arranged in layers closely applied to the body and neck of the posterior lobe and the under surface of adjacent parts of the brain. Colloid material occurs between the cells, which passes into the adjacent nervous substance, to be absorbed by lymphatics which carry it to the cavity of the posterior lobe, and into the third ventricle of the brain. The existence of colloid cysts in the pituitary closely resembling those of the thyroid has led many observers to the conclusion that the function of the two glands is similar, and that after removal of the thyroid the pituitary may take on its work vicariously. After extirpation of the thyroid gland, the cells of the pars intermedia do manifest increased activity, and the colloid matter increases, but this is all that can be said at present in favor of such a view; the removal of the two organs produces very different symptoms; injection of extracts produces very different effects; moreover, the pituitary contains no iodine, therefore the colloid material is a different substance in the two cases.

(3) The *posterior lobe.* This is connected to the floor of the third ventricle, of which it forms a developmental outgrowth; in some animals (cat) it remains hollow throughout life, in others (dog) the neck alone remains hollow, and in most (including man) both body and neck are solid, with traces of a cavity in the neck. Though developed from the brain, it contains in the adult no nerve cells, but consists mainly of neuroglia. It is surrounded and invaded by the epithelium cells and colloid matter derived from the pars intermedia. It plays the part of a brain gland in virtue of these epithelial cells. What the use of the secretion into the third ventricle may be, is far from clear.

The pituitary body is essential to life. Paulesco, and

later Harvey Cushing and Horsley, found that total removal of the organ is fatal in a few days. The same result follows *entire* removal of the anterior lobe. On the other hand, removal of the posterior lobe produces no such effect. Partial removal of the anterior lobe produces a condition known as hypopituitarism, in which adiposity accompanied by (or secondary to) atrophy of the organs of generation are the most marked signs. If the operation is done before adolescence, there is a persistence of sexual infantilism. The transplantation of the organ from another animal, or injection of anterior lobe extracts prolongs the life of animals after total extirpation. In many of Horsley's experiments no such symptoms occurred, even although only minute portions of the anterior lobe were left behind.

THE SUPRARENAL CAPSULES

There are some points of interest in the development and comparative physiology of the suprarenals. In the mammals the medullary portion is developed in connection with the sympathetic, and is at first distinct and outside the cortical portion which is developed in connection with the upper part of the Wolffian body; it gradually insinuates itself within the cortex (Mitsukiri). In Elasmobranch fish the suprarenals consist throughout life of separate portions; one, the interrenal body, is median in position and single; this corresponds to the cortex of the mammalian suprarenal; extracts of this are inactive, and in the Teleostean fish, where it is the slow representative of the suprarenal, it may be removed without any harm to the animal. The other portion of the Elasmobranch suprarenal is paired, and derived from the sympathetic

ganglia. This corresponds to the medulla; it contains the same chromogen as the medulla of the mammalian suprarenal, and extracts of it have the same physiological action (S. Vincent).

Note: The tissue of the suprarenal medulla is often called *chromophil* tissue, on account of the ready way in which it stains with chromic salts. Such tissue is, moreover, not confined to the suprarenal, but is found in scattered patches in the retro-peritoneal region and in many sympathetic ganglia, especially in the abdomen. The histological resemblance is accentuated by the presence of numerous sympathetic cells in the suprarenal medulla. The chromophil tissue wherever found always yields adrenaline.

ENERVATION OF THE SPLEEN

It has been found by experiment that when the splenic nerves are cut the spleen enlarges, and that contraction can be brought about by stimulation of the peripheral ends of the divided nerves. If the splenic nerves are not cut, contraction is produced by (1) stimulation of the spinal cord; (2) reflexly by stimulation of the central stumps of certain divided nerves, e. g., vagus and sciatic; (3) by local stimulation by an electric current. These splenic nerve fibers leave the spinal cord in numerous thoracic anterior roots; they have cell stations in the sympathetic chain (Schafer) or semi-lunar ganglia (Langley).

NERVOUS MECHANISM—STOMACH

The stomach has a double nerve supply, and the fibers terminate in the plexus situated between its muscular coats. The two seats of nerves are:

(1) The Vagus. The cell stations for these fibers

appear to be in the terminal ganglia of the plexus, though possibly some may occur in the ganglia trunci vagi. These nerves are accelerator; when stimulated, the result is increase of peristalsis.

(2) The Sympathetic. These leave the spinal cord by the anterior roots of the spinal nerves from the fifth to the eighth thoracic; their cell stations are in the coeliac ganglion, and the post-ganglionic fibers which arise there pass to the stomach by branches of the splanchnic nerves. The sympathetic fibers are inhibitory, when they are stimulated peristalsis ceases.

NERVOUS MECHANISM—SMALL INTESTINE

The small intestine like the stomach, has a double nerve supply.

(1) The Vagus. As in the case of the stomach, these fibers are accelerator, and stimulation induces peristaltic movements. If the intestine is contracting peristaltically before the stimulus is applied, the movements are inhibited for a brief period, after which they are greatly augmented.

(2) The Sympathetic. These fibers leave the spinal cord by the anterior roots of the sixth thoracic to the first lumbar, pass through the lateral chain, but do not reach their cell-stations until they arrive at the superior mesenteric ganglia; thence they pass as non-medullated, post-ganglionic, fibers to the muscular coats. Stimulation of these nerves causes inhibition of any peristaltic movements that may be present. They also contain vaso-motor fibers, and section of these leads to vaso-dilatation and a great increase of very watery succus entericus.

These two sets of nerves, (vagus and sympathetic) terminate in the ganglionated plexus of Auerbach,

situated between the two muscular layers of the intestinal wall.

Under normal circumstances, the intestinal movements are regulated from the central nervous system via these two channels. Nevertheless, after all the nerves are cut, the movements continue, and may remain normal for months. This independence of control from the central nervous system justifies the use of the term autonomic. The true peristaltic waves are, however, co-ordinated reflex actions, the centers for the reflex being situated in the ganglion cells of Auerbach's plexus. The movements entirely cease if the intestine is painted with cocaine, or if nicotine is injected, for under the influence of these drugs the synaptic junctions of the ganglion cells are paralyzed. The importance of the integrity of the plexus was also shown by Magnus in his experiments with strips of intestinal muscle; such strips are incapable of spontaneous rhythm if the nerve plexus is not removed with them.

THE INNERVATION OF THE GASTRIC GLANDS

As long ago as 1852 Bidder and Schmidt showed in a dog with a gastric fistula that the sight of food caused a secretion of gastric juice; and in 1878 Richet observed that in a man with complete occlusion of the gullet the act of mastication caused a copious flow of gastric juice. There could therefore have been no doubt that the glands are under the control of the nervous system, but the early attempts to discover the secretory nerves of the stomach were unsuccessful. The Russian Physiologist Pawlow solved the problem by the employment of new methods. He experimented on dogs. In the first place he separated off the diverticulum, and by careful experiments he showed that the secretion of

this small stomach is an exact sample, both as regards composition and rate of formation, of that which occurs in the main stomach, which is still left in continuity with the æsophagus above and the duodenum below.

Another procedure adopted was to divide the æsophagus, and to attach the two cut ends to the opening in the neck. The animal was fed by the lower segment, but any food taken into the mouth, or any saliva secreted there, never reached the stomach, but fell out through the opening of the upper segment. These animals were kept alive for months, and soon accommodated themselves to their new conditions of life. The animals could thus be subjected, (1) real feeding, (2) sham feeding, by allowing them to eat food which subsequently tumbled out through the neck opening, and (3) psychical feeding, in which the animal was shown food but was not allowed to eat it. The psychical element is important.

Mechanical excitation of the stomach wall produces no secretion. If water is introduced there is a slight flow, and even if meat is introduced into the main stomach without the knowledge of the dog, the juice formed is scanty and of feeble digestive power.

There is, moreover, no connection between the acts of mastication and swallowing with that gastric secretion. Sham feeding with stones, butter, salt, pepper, mustard, extract of meat and acid, though it excited a flow of saliva, produced no effect on the stomach. If, however, meat was used for the sham feeding, an abundant and active secretion occurred in the stomach (that of the small stomach was actually examined) after a latency of about five minutes. The secretion is thus adapted to the kind of food the dog has to digest; the larger the proportion of protein in the diet, the more

abundant is the juice, and the richer both in pepsin and acid.

Indeed, if the animal is hungry and is shown the meat and not allowed to swallow it, the effect is almost as great. The following striking experiment also shows the importance of the psychical element. Two dogs were taken, and a weighed amount of protein introduced into the main stomach of each without their knowledge; one was then sham fed on meat, and one and a half hours later the amount of protein digested by this dog was five times greater than that which was digested by the other.

In the meat, however, it is not the protein which acts most strongly as the stimulus. Egg white, for instance, is not a stronger stimulus than water, but extract of meat is a powerful stimulus. What the exact extractives are that act in this way is not yet known, and Herzen has since shown that dextrin acts even more powerfully. Herzen distinguishes between *succagogues* (juice-drivers) such as Liebig's extract, and *peptogens* such as dextrin, which produces not only an increased flow, but a juice rich in pepsin-hydrochloric acid. The products of proteolysis are also peptogenic, so that when once digestion has started, a stimulus for more secretion is provided.

If the vagi are cut (below the origin of the recurrent laryngeal to avoid paralysis of the larynx), and then sham feeding is performed with meat, no secretion is obtained; the vagi, therefore, contain the secretory fibers. The experiment of stimulating the peripheral end of the cut nerve confirmed this hypothesis. The nerve was cut in the neck four or five days before it was stimulated. In this time degeneration of the cardio-inhibitory fibers took place, so that stoppage of

the heart did not occur when the nerve was stimulated. Under these circumstances a secretion was obtained with a long latency; the latency is explained by the presence of secretory-inhibitory fibers. Atropine abolishes the action of the vagus. In other animals the spinal cord was cut at the level of the first cervical nerve, and the animal kept alive by artificial respiration; the vagus nerve was then cut, and its peripheral end stimulated. An abundant secretion usually followed. Division of the cord renders an anæsthetic unnecessary, and also prevents the afferent impulses set up by the operation passing to the vagal centers, and thus exciting the inhibitory impulses which pass down the vagus, and tend to prevent secretion under ordinary circumstances.

Pawlow thinks that the sympathetic also contains some secretory fibers, but that has not yet been proved.

THE SO-CALLED PERIPHERAL REFLEX SECRETION OF THE PANCREAS

One of the most effective ways of producing a flow of pancreatic juice is to introduce acid in to the duodenum. Popielski and Wertheimer and Le Page showed that this flow still occurs when the nerves supplying the duodenum and pancreas have been cut through. Wertheimer also mentions that the flow can be excited by injection of acid into the jejunum, but not when it is injected into the lower part of the ileum. These authors concluded that the secretion is a local reflex, the centers being situated in the scattered ganglia of the pancreas, or, in the case of the jejunum, in the ganglia of the solar plexus.

This subject has been investigated by Starling and Bayliss, and the results they have obtained are most

noteworthy. They consider that the secretion cannot be reflex, since it occurs after extirpation of the solar plexus, and destruction of all nerves passing to an isolated loop of intestine. Moreover, atropine does not paralyze the secretory action. It must, therefore, be due to direct excitation of the pancreatic cells, by a substance or substances conveyed to the gland from the bowel by the blood stream. So many of the connections between organs are made by nerves (the telegraphic service of the body), that we are apt to forget the other messenger, the blood, whom we may compare to the postman.

The exciting substance is not acid; injection of 0.4 per cent of hydrochloric acid into the blood stream has no influence on the pancreas.

THE SECRETORY NERVES OF SALIVARY GLANDS

The *submaxillary and sublingual.* They receive two sets of nerve fibers; namely, from the chorda tympani and sympathetic.

The *chorda* tympani is given off from the seventh cranial nerve in the region of the tympanum. After quitting the temporal bone it passes downwards and forwards, and joins the lingual nerve, with which it is bound up for a short distance. On leaving the lingual nerve it traverses the *submaxillary ganglion;* it then runs parallel to the duct of the gland, gives off a branch to the sublingual gland, and others to the tongue. The main nerve enters the hilus of the submaxillary gland, where it traverses a scattered collection of ganglion cells concealed within the substances of the gland, and which may be called after its discoverer, *Langley's ganglion.*

The *sympathetic* branches to these two glands are

derived from the plexus around the facial artery, and accompanies the arteries which supply the glands.

Section of the nerves produces no immediate result, but after a few days a scanty but continuous secretion of thin watery saliva takes place. This is called *paralytic secretion,* and is produced either by the activity of the local nervous mechanism, which is then uncontrolled by impulses from the central nervous system, or else it is a degenerative effect analogous to the fibrillar contractions which occur in degenerating muscles after severance of their nerves. If the operation is performed on one side, the glands of the opposite side also show a similar condition, and the thin saliva secreted there is called the *antilytic* secretion.

Stimulation of the peripheral end of the divided chorda tympani produces an abundant secretion of saliva, which is accompanied by vaso-dilatation. Stimulation of the peripheral end of the divided sympathetic causes a scanty secretion of thick viscid saliva, accompanied by vaso-constriction.

The abundant secretion of saliva which follows stimulation of the chorda tympani is not merely the result of a filtration fluid from the blood vessels in consequence of the largely increased circulation through them. This is proved by the fact that, when the main duct is obstructed, the pressure within it may considerably exceed the blood pressure in the arteries, and also that when into the veins of the animal experimented upon, some *atropine* has been previously injected, stimulation of the peripheral end of the divided chorda produces considerable vascular dilatation without any secretion of saliva accompanying it. Again, if an animal's head is cut off, and the chorda is rapidly exposed and stimulated with an interrupted current, a secretion

of saliva ensues for a short time, although the blood flow is necessarily absent. These experiments serve to prove that the chorda contains two sets of nerve fibers, one set (vaso-dilator), which, when stimulated, cause the vessels to dilate, while another set, which are paralyzed by atropine, directly stimulate the cells themselves to activity, whereby they secrete and discharge the constituents of the saliva which they produce. On the other hand, the sympathetic fibers are also of two kinds, vaso-constrictor and secretory, the latter being paralyzed by atropine. The chorda tympani nerve is, however, the principal nerve through which efferent impulses proceed from the central nervous system to excite the secretion of these glands.

The function of the ganglia has been made out by Langley by nicotine method. The ganglia are called cell stations on the course of the fibers to the submaxillary and sublingual glands. Nicotine applied locally has the power of paralyzing nerve cells, but not nerve fibers. If the submaxillary ganglion is painted with nicotine, and the nerve stimulated on the central side of the ganglion, secretion from the submaxillary gland continues, but that from the sublingual gland ceases. The paralyzed nerve cells in the ganglion act as blocks to the propagation of the impulse, not to the submaxillary, but to the sublingual gland. The cell station for the submaxillary fibers is in Langley's ganglion.

The difference between the two secretions is not only one of amount, for the "chorda secretion" is continuous as long as the nerve is stimulated; it is like the fluid from a tap. The "sympathetic secretion," on the other hand, stops after about fifteen seconds, and may be compared to what happens when one squeezes a sponge. These facts are in accordance with observations on the

loss of water sustained by the blood when the nerves are stimulated.

In similar experiments on sympathetic saliva there was no evidence of any loss of water from the blood. Sympathetic saliva comes either from the substance of the cells, or from the ducts, and without going into the evidence at length, the former is, at any rate in part, the correct explanation. It would appear, therefore, that the fundamental difference between the two nerves is that the chorda confers upon the cells the power of recouping themselves from the blood, while this is denied to the sympathetic.

This is the salient point, but it is certain that the rate of blood flow can modify the rate of salivary secretion, thus squeezing the artery during chorda stimulation lessens the flow of blood and flow of saliva, though the latter still remains continuous; and in the cat it is possible, on prolonged stimulation of the sympathetic, for the initial constriction of the arteries to pass off, and yet there is no continuous secretion.

Salivary secretion cannot be due to osmosis, for the saliva is poorer in salts than the blood, and, therefore, the stream of water, if osmosis existed, would be back to the blood from the saliva. The cells of the salivary glands are really doing work or can be made to do so.

PAROTID GLAND

This gland also receives two sets of nerve fibers analogous to those we have studied in connection with the submaxillary gland. The principal secretory nerve fibers are glosso-pharyngeal in origin; the sympathetic is mainly vaso-constrictor, but in some animals it does contain a few secretory fibers also.

Reflex secretion. Under ordinary circumstances the

secretion of saliva is a reflex action. The principal afferent nerves are those of taste; but the smell or sight of food will also cause "the mouth to water"; and under certain circumstances, as before vomiting, irritation of the stomach has a similar effect. These sensory nerves stimulate a center in the medulla, from which efferent secretory impulses are reflected along the secretory nerves (chorda tympani, etc.) to the glands.

Pawlow has recorded some interesting observations on the salivary glands. He made an external fistula of the submaxillary duct in the dog, and found that the sight of food, the smell of food, or the administration of any kind of food caused secretion; acid or even sand introduced into the mouth produced a similar effect. By means of similar experiments on the parotid secretion, very different results were obtained. If the dog was shown meat, or the meat was given to it to eat, there was practically no secretion. If, however, the meat was given as dry powder, a copious secretion follows; dry bread produced a similar effect; in fact, the parotid secretion flows freely if dry food is simply shown to the animal; of course, in all such experiments the dog must be hungry.

Such observations emphasize the psychical element involved in secretion, and point out also the adaptation of the secretory process to the needs of the animal; thus the submaxillary saliva, which is mainly a lubricant in virtue of its mucin, flows whatever the food may be, whereas moist food requiring no watery saliva from the parotid excites the flow of none.

NERVOUS MECHANISM OF DEGLUTITION

The nerves engaged in the reflex act of deglutition are: *Sensory* branches of the fifth cranial nerve

supplying the soft palate and tongue; glosso-pharyngeal, supplying the tongue and pharynx; the superior laryngeal branch of the vagus, supplying the epiglottis and the glottis; while the motor fibers concerned are: branches of the fifth, supplying part of the digastric and mylo-hyoid muscles and the muscles of mastication; the bulbar part of the spinal accessory through the pharyngeal plexus, supplying the levator palati, probably by rootlets which are glosso-pharyngeal in origin; the glosso-pharyngeal and vagus, and possibly the bulbar part of the spinal accessory, supplying the muscles of the pharynx through the pharyngeal plexus; the vagus in virtue of its spinal accessory roots, supplying the muscles of the larynx through the inferior laryngeal branch, and the hypo-glossal, the muscles of the tongue. The nerve centers by which the muscles are harmonized in their action are situated in the medulla oblongata.

Stimulation of the vagi gives rise to peristalsis of the æsophagus. The cell station of these fibers are in the ganglion trunci vagi. Divisions of both pneumogastric nerves gives rise to paralysis of the æsophagus and stomach, and firm contraction of the cardiac orifice. These nerves, therefore, normally supply the æsophagus with motor and the cardiac sphincter with inhibitory fibers. If food is swallowed after these nerves are divided, it accumulates in the gullet and never reaches the stomach.

In discussing peristalsis we arrive at the conclusion that it is an inherent property of muscle rather than of nerve, though normally it is controlled and influenced by nervous agency. This nervous control is especially marked in the æsophagus; for if that tube is divided, across, leaving the nerve branches intact, a

wave contraction will travel from one end to the other across the cut.

ELECTRICAL VARIATIONS IN GLANDS

These have been studied in many glandular organs, but especially in the salivary glands and skin.

In the submaxillary gland the hilus is electro-negative to the external surface of the organ; a current, therefore, passes from hilus to surface through the galvanometer. If the chorda tympani is stimulated by rapidly interrupted shocks, the surface becomes still more positive. This is the opposite to what occurs in a muscle; there the current of action is in the reverse direction to the demarcation current; the change in the gland is a positive variation in the arithmetical sense.

The two changes are believed to be due to the fact that secretory nerves are of two kinds: anabolic, which increases the building up of the grandular protoplasm, and katabolic, which increases the disintegrative side of metabolism, and so lead to secretion. But this explanation has been very seriously questioned. In fact, it is wiser to confess that the ultimate meaning of the electrical changes in the salivary glands is entirely unknown.

THE NERVES OF THE KIDNEY

These are derived from the renal plexus of each side. The renal plexus consists of both medullated and non-medullated nerve fibers with collections of ganglion cells. Fibers from the anterior roots of the eleventh, twelfth and thirteenth dorsal nerves (in the dog) pass into this plexus. They are both vaso-constrictor and vaso-dilator in function. The nerve cells on the course

of the constrictor fibers are situated in the cœliac, mesenteric, and renal ganglia; the nerve cells on the course of the dilator fibers are placed in the solar plexus and renal ganglia. We have, at present, no knowledge of true secretory nerves to the kidney, and the amount of urine is influenced, to a certain extent at any rate, by the blood pressure in its capillaries. We know, however, that the amount of urine does not wholly depend on the height of the blood pressure; and one very striking fact in relation may be mentioned now, namely, that if the blood pressure is increased without allowing the blood to flow, the amount of urine formed is not increased. This can be done by ligaturing the renal vein; the blood pressure within the kidney then rises enormously, but the flow of urine stops.

(1) If the renal nerves are divided, the renal arterioles relax, and the pressure in the renal capillaries rises. This leads to an increased flow of urine, which is accompanied by an increase in the volume of the kidney, as shown by the oncometer. Stimulation of the divided nerves produces diminution in a flow of urine and a shrinkage of the kidney due to constriction of its blood vessels. These nerves also contain vaso-dilator fibers, which are excited when a slow rate of stimulation is used. If the splanchnic nerves are experimented with instead of the renal, the effects are not so marked, as these nerves have a wide distribution, and section leads to vascular dilatation in the whole splanchnic area; hence, the increase of pressure in the renal capillaries is not so noticeable.

(2) Puncture of the floor of the fourth ventricle in the neighborhood of the vaso-motor center (close to the spot, puncture of which produces glycosuria) leads to

relaxation of the renal arterioles and a consequent large increase of urine.

INTESTINES, UTERUS, ERECTION

Nervous Mechanism. The large intestine resembles the rest of the alimentary canal in having a double nerve supply.

(1) The *sympathetic.* These fibers leave the cord by the lower lumbar anterior roots; these pass through the lateral chain and reach their cell stations in the inferior mesenteric ganglion; the post-ganglionic fibers arising there, pass by the colonic nerves to the colon, and by the hypogastric nerve to the rectum and internal anal sphincter.

(2) The *nervus erigens.* This takes the place of the vagus, which forms the second source of nerve supply to the stomach and small intestine. This nerve is excitatory to both coats of the muscular wall, whereas the sympathetic is inhibitory to the internal sphincter.

The fibers which pass to the rectum by the pelvic nerves of nervi erigentes arise from the third sacral nerve, and have their cell stations in the hæmorrhoidal nerve plexus, which is the name given to this portion of the plexus of Auerbach.

The voluntary muscles, namely, the external anal sphincter and the levator ani, are supplied by the fourth sacral nerve, which arises from nerve cells in the conus terminalis of the spinal cord.

If Starling's experiment of pinching a spot in the large intestine is performed, much the same result follows as in the small intestine; the wave of inhibition which travels downwards is well seen, but the upward wave of contraction is not so marked as in the small intestine. Stimulation of the sympathetic (hypogas-

tric) nerve fibers produces movements of the colon and rectum, and inhibition of the internal sphincter. That is the main phenomenon of the act of defæcation. If the lower part of the spinal cord is destroyed, defæcation still occurs, but it is an unconscious act, and the reflex is imperfectly executed; the hypogastric part of the mechanism is intact, and probably the reflex center concerned is, as in the small intestine in the peripheral ganglia of Auerbach's plexus, but the destruction of the conus terminalis prevents the normal reflexes taking place in which the levator ani and external muscles may lead to incontinence of fæces.

Uterine reflexes. Uterine contractions can be induced by rectal injections, the passage of a foreign body into the uterus, the application of the child to the breast, and by other means. In animals faradization of the central end of the first sacral nerve produces the same result. The contractions of the uterus are therefore reflex. Several cases have been recorded in which parturition has occurred normally in women who have had the cord divided across completely in the thoracic region.

It is thus evident the center must be a lumbar one. In such cases the uterine contractions technically called "pains" are strong, but pain is, of course, absent. The communication with the lumbar region appears to be principally by the first three lumbar nerves. Similar observations have been made experimentally in animals, and in one of Goltz and Ewald's dogs in which the cord had been removed from the lower thoracic region downwards, pregnancy followed coitus, and terminated with successful parturition. The mammary glands enlarged as usual in such cases, even when, as is Routh's well known case (where the cord was com-

pletely destroyed at the seventh thoracic segment), there can be no spinal communication between the pelvis and the breast.

Erection. This can be excited in man even immediately after a transverse lesion of the cord; so also can ejaculation, but not so commonly. The evidence in favor of such acts being spinal reflexes is very complete in the case of animals.

Du Bois Raymond found that the spinal cord, like a nerve, exhibits a demarcation current between its longitudinal surface and a cross-section, and that a diminution of this current occurs on excitation (negative variation). Gotch and Horsley investigated the currents of the cord very thoroughly. If the Rolandic area of the cortex is stimulated, and a portion of the thoracic region of the spinal cord is led off to a galvanometer, a persistent negative variation followed by a series of intermittent variations is observed. This exactly corresponds to the tonic spasm followed by colonic contractions which occur in the muscles excited by this means.

The galvanometer in the hands of these observers also proved to be a valuable instrument for determining the paths taken by nervous impulses in the cord. One example will suffice: If the central end of one sciatic nerve is stimulated, the chief electrical variation in the cord is noticed to be obtained when the same side of the cord is led off to the galvanometer, but a certain amount of electrical variation in the cord is obtainable from the opposite side of the cord. This coincides with the fact ascertained by other methods, that the main sensory channel is on the same side of the cord as the entering nerves, but that there is a certain amount of decussation below the level of the bulb.

Electromotive changes also occur during activity in the cortex cerebri, but they have not been much studied, and we do not know whether they have their seat in the gray or in the underlying white matter.

THE SWEAT

The amount of secretion is influenced by the vasomotor nerves; an increase in the size of the skin vessels leads to increased, a constriction of the vessels to diminished, perspiration. There are also special secretory fibers, stimulation of which causes a secretion even when the circulation is suspended, as in a recently amputated limb. These fibers are paralyzed by atropine. They are contained in the same nerve trunks as the vasomotor nerves, as are also the nerve fibers of the sweat glands which act during the expulsion of the secretion. The secretory nerves for the lower limbs issue from the spinal cord by the last two or three dorsals, and the first two or four lumbar nerves (in the cat); they have cell stations in the lower ganglia of the lateral chain and pass thence to the sciatic nerve. They are controlled by a center in the upper lumbar region of the cord; those for the upper limbs leave the cord by the sixth, seventh and eighth anterior thoracic roots, have cell stations in the ganglion stellatum and ultimately pass to the cervical enlargement of the cord. The secretory fibers for the head pass in the cervical sympathetic, and in some branches of the fifth cranial nerves. These subsidiary centers are dominated by one in the medulla oblongata (Adamkiewicz).

The sweat centers may be excited directly by venous blood, as in asphyxia, or by over-heated blood (over 45° C.), or by certain drugs, or reflexly by stimulation of afferent nerves such as the curaral and peroneal.

Nervous diseases are often accompanied with disordered sweating, thus unilateral perspiration is sometimes seen in cases of hemiplegia. Degeneration of the anterior nerve cells of the cord may cause stoppage of the secretion.

REFLEX ACTION IN MAN

Each action is affected through an afferent sensory nerve, a system of nerve cells in the cord termed the reflex center, and an efferent motor nerve; the whole constitutes what is called the reflex arc. *The absence of certain reflexes may determine the position in the spinal cord which is the seat of disease.*

Two forms of reflex action must be distinguished:

1. Superficial reflexes. These are co-ordinated reflex actions, and are excited by stimulation of the skin.

2. Deep reflexes or tendon reflexes.

Superficial reflexes are obtained by a gentle stimulation, such as a touch on the skin; the muscles beneath are usually affected, but muscles at a distance may be affected also. Thus a prick near the knee will cause a reflex flexion of the hip.

The most important of these reflexes are:

a. Plantar reflex: withdrawal of the feet when the soles are tickled.

b. Gluteal reflex: a contraction in the gluteus when the skin over it is stimulated.

c. Cremasteric reflex: a retraction of the testicle when the skin on the inner side of the thigh is stimulated.

d. Abdominal reflex: a contraction of the muscles of the abdominal wall when the skin over the side of the

abdomen is stroked; the upper part of this reflex is a very definite contraction at the epigastrium, and has been termed the epigastric reflex.

e. A series of similar reflex actions may be obtained in the muscles of the back, the highest being in the muscles of the scapula.

f. In the region of the cranial nerves the most important reflexes are those of the eye: (1) the conjunctival reflex, the movement of the eyelids when the front of the eyeball is touched; and (2) the contraction of the pupil on exposure of the eye to light and its dilatation on stimulation of the skin of the neck.

When the muscles are in a state of slight tension a tap on their tendons will cause them to contract. The two tendon reflexes which are generally examined are the patella tendon reflex or knee jerk, and foot phenomenon or ankle clonus.

The *knee jerk*. The quadriceps muscle is slightly stretched by putting one knee over the other; a slight blow on the patella tendon causes a movement of the foot forwards.

Ankle clonus. The hand is pressed against the sole of the foot, the calf muscles are thus put on the stretch and they contract, and if the pressure is kept up a quick succession or clonic series of contractions is obtained. This, however, is not readily obtained in health.

The phenomena depend for their occurrence on the integrity of the reflex arc. Disease or injury to the afferent nerve, efferent nerve, or spinal gray matter, abolishes them. Thus they cannot be obtained in locomotor ataxy (damage to the posterior nerve roots), or in infantile paralysis (damage to the anterior horns or gray matter).

They are excessive in those conditions which increase reflex irritability, such as severance of brain from cord, and in lateral sclerosis.

In order that the muscle may respond, it is necessary that it be in an irritable condition. This is accomplished by putting it slightly on the stretch, and so calling forth the condition called tonus, and thus a readiness to contract on slight provocation. Until the last few years considerable doubt existed as to whether the tendon reflexes were true reflex actions, because it was asserted that the time intervening between the stimulus and the muscular response was too short. Now that we know that nerve impulses are in man propagated at the rate of 120 meters per second this difficulty has disappeared. Jolly had made careful time measurements and demonstrated that in the knee jerk there is sufficient time for the nerve impulse to travel to the spinal cord and back again, but that the time occupied in the cord itself is only about half that which is necessary in the case of ordinary co-ordinated reflex actions. This is explicable on the assumption that the tendon reflexes are subserved by the collaterals of the entering afferent fibers which go direct to the anterior horn cells, whereas ordinary reflexes are worked through intermediate neurons, and therefore have to pass through additional synapses.

The increased rapidity of a tendon reflex is useful, for a sudden strain on a ligament would rupture some of its fibers or lead to injury of the joint surfaces if too great a time intervened before the muscles could contract and so save the joint.

The exact course of the reflex as concerned in the knee jerk has been worked out by Sherrington in the monkey. The nerve fibers are mainly those which pass

(1) to and from the crureus by the anterior crural nerve, and (2) to and from the hamstrings of the sciatic nerve. The fibers which supply the crureus arise from the spinal nerve roots which in man correspond to the third and fourth lumbar; the hamstring supply is from the fifth lumbar and first and second sacral roots.

Lombard's experiments upon the knee jerk indicate that it is sometimes more readily obtained even in the same person than at other times. It varies with changes in mental activity, and during sleep may be entirely absent. It is increased and diminished by whatever increases or diminishes the relative state of irritability of the nervous system as a whole.

Many explanations have been offered for the phenomenon; one is the "overflow" theory, that is, motor impulses from the brain which produce a contraction of hands or jaw will not only affect the lower centers concerned in such movements, but will also overflow to other regions, for instance, those which come into play in the knee jerk and influence motor irritability there. The "drainage" theory of McDougall may possibly explain reinforcement; the *drainage of nervous potential to one part will lessen the resistance of the synaptic junctions and cause a drainage of nervous energy from other parts, and so allow reflex actions to be more readily elicited there.* This theory is fully in accord with our knowledge on electronic or radio circuits and is fully discussed in the chapter on "Electrons," "Electro-Chemistry of Proteins," and "Synapses."

The study can be extended into Reciprocal Action of Antagonistic Muscles and other experiments too numerous for our purpose.

When an afferent nerve is stimulated, the impulse

enters that complex network of conducting paths, which is called the central nervous system. So numerous are the potential connections in this labyrinth that the impulse may, under such abnormal conditions as strychnine poisoning, radiate in all directions, and be discharged so as to throw all the muscles of the body into action. But under normal circumstances the irritation is limited to certain lines, which increase in number with the strength of the entering impulse. The general pattern of the nervous web remains fairly constant, but its details are subject to great variations, and a new stimulus may act like a tap on a kaleidoscope, and throw a new pattern into being.

At the commencement of every reflex arc is a receptive neuron extending from a sensory surface to the brain or cord, and this is a private path exclusively occupied by impulses from its own receptive points on the surface of the body. These impulses pass along certain association tracts or internuncial paths in the central nervous system, and at the termination of the arc we have a final neuron which acts as the conducting link between the central nervous system and the muscle or gland which it supplies. This final neuron does not subserve exclusively impulses generated at one receptive source, but can be used in the conduction of impulses generated at many points of the body's surface. The arm muscles, for instance, can be thrown into play in response to visual, auditory, tactile and other sensations. The final neuron thus differs from the initial neuron in being public, not private, and may be spoken of as the final common path. Of course, in very reflex action we are not really concerned with individual neurons, but with thousands of them acting in harmony; still, for descriptive purposes, it is well to speak of one

set of neurons only as a sample of the rest. An ordinary motor nerve is thus a collection of many final common paths.

Now let us suppose that two stimuli are acting on different parts of the body's surface, each of which would produce impulses that ultimately reach the same final common path together, though they may throw the motor organ into action in rather a different way. Under such circumstances it is found that the occupation of the public path by one impulse prevents it being simultaneously used by the other. One reflex or the other takes place, but not both of them.

The presence of synapses and their construction allows a reasonable and scientific explanation for this and is discussed in detail later on.

For the investigation of such a problem, the "scratch reflex" of the dog is one that lends itself admirably. This can best be studied in the "spinal" dog, that is, in a dog in which cerebral influence is shut off by division of the spinal cord in the lower cervical region. If the skin over a large saddle-shaped area covering the shoulders and back is gently irritated on one side, the hind leg of the same side executes scratching movements, which involve flexor muscles principally. The rate of scratching is about 4 per second, and each movement is presumably a short tetanus. The best "artificial flea" to employ is a weak faradic current, and it is the nerves at the roots of the hair follicles which are specially susceptible when eliciting the reflex. The internuncial paths in the cord are in the lateral part of the lateral column, and division of that region of the cord abolishes the reflex.

But there is another form of stimulation which also throws the same flexor muscles into action, although in

rather a different way, and that is stimulation of the sole of the foot. The foot and leg are withdrawn, and the action is a steady one and not a succession of rhythmic discharges as in scratching. Both reflexes, however, end in the same final common path. And if while scratching is being elicited by stimulation of the shoulder, the foot is then stimulated simultaneously, scratching immediately ceases; one set of impulses has displaced the other from the final common path. If then one ceases to stimulate the foot, the scratch reflex returns if the irritation of the shoulder is kept up.

But there is also another way in which the inhibition of reflexes may be produced. The contraction of one set of muscles is usually accompanied by relaxation of its antagonists, and the contraction of the flexors in the scratch reflex may therefore be inhibited by making the antagonistic muscles (the extensors) contract. Further, the scratch reflex is unilateral, but this does not mean that the muscles supplying the other legs are inactive, for they must act in such a way as to support the dog on three legs, while it scratches with the fourth. So if the right shoulder is stimulated, the right hind leg scratches; if the left shoulder is stimulated, the left hind leg scratches; but if both shoulders are stimulated together, only one or the other leg scratches, not the two at once; parts of the final paths are common to both sides, and there is a struggle for their occupation. Some instances of reinforcing action were found, for example, if two points of the skin of one shoulder are stimulated with a very feeble current, neither stimulus alone may be sufficient to evoke the scratch reflex, but the two together may elicit it. In order to attain this result the two points of skin must be fairly close together.

"AFFERENT-EFFERENT NERVES"

The afferent neurons (private paths) of the body are about five times more numerous than the efferent (final common paths), and in the struggle for the occupation of these public paths by the impulses that enter the central nervous system by the more numerous private paths, three factors are specially concerned: (1) Strength of stimulus; the stronger the stimulus the better change the resulting impulse has of getting round to the motor organ. (2) Character of impulse; sensations of painful nature and sexual feelings win the final path easily; it is a matter of common experience that such sensations dominate and even exclude other sensations; a man with a bad toothache is not likely to take much notice of anyone who pulls his coat tails. (3) Fatigue; at the end of a long stimulation, a stimulus applied to a fresh reflex arc has a better chance of capturing the common path.

The spinal gray matter contains centers which regulate the operation of many involuntary muscles. Some of these centers are: The cilio-spinal center controls the dilatation of the pupil; it is situated in the lower cervical region, reaching as far down as the origin of the first to the third thoracic nerve.

Subsidiary vaso-motor centers. The principal vaso-motor center is situated in the bulb, and subsidiary centers are scattered through the spinal gray matter. The same is probably true for all the muscular viscera, but particular study has been directed to those in the pelvis, the centers for micturition, defæcation, erection, and parturition are contained in the lumbo-sacral region of the cord. If the spinal cord is cut through above the situation of these centers, the result is in general

terms that any influence of the higher (voluntary) centers over these actions is no longer possible. The actions in question are then simply reflex ones occurring unconsciously at certain intervals and set in movement by the peripheral stimulus (fullness of bladder, or of rectum, etc.). If the portion of the cord where these centers are placed is entirely destroyed, the result is paralysis of the muscles concerned, though in certain cases, even after such a severe injury, some amount of recovery has been noticed, which must be attributed to the peripheral ganglia being able to play the part of reflex centers.

The desire to void the urine arises from a sense of fullness of the bladder, and the increase of pressure in this viscus, which results from its distension, is probably the most important factor in the causation of the reflex. Mosso states that in the dog's bladder a pressure of 20 cms. of water sets the reflex in action.

The afferent impulse so produced finds its way to the sacral region of the cord chiefly through the second and third sacral nerves, and stimulates the so-called vesical center, which is situated in the gray matter there. The reflex takes place perfectly well in an animal whose spinal cord has been cut across as low as the lower part of the lumbar region. It has, therefore, been proved that the reflex center must be situated below this point. In such animals there is no consciousness of the afferent impulse, and the same is true for the human subject with corresponding injuries to the spinal cord. Such animals or men have also no voluntary control over the act; it occurs in them purely reflexly.

The efferent nerves to the bladder fall into two sets: (1) the nervus erigens; this is undoubtedly the more important of the two. Stimulation of this nerve causes

contraction of the bladder, and relaxation of its sphincter, the two necessary acts by which the urine is expelled. (2) The hypogastric nerves; pre-ganglionic fibers leave the cord in the lumbar region, pass thence to the inferior mesenteric ganglion, from the cells of which the post-ganglionic fibers ultimately reach the bladder by the hypogastric nerves. Much difference of opinion has been expressed regarding the action of these nerves, but in most animals they cause constriction of the sphincter, and in some cases relaxation of the bladder walls also. The hypogastric nerves would therefore appear to be the functional antagonists of the nervi erigentes. In many animals the bladder constantly exhibits rhythmic contractions.

In theory, therefore, micturition is a reflex action, but in practice it is a voluntary act, and the voluntary muscles of the abdomen press upon the bladder and assist its emptying. It is only in the cases of cord injury or disease already alluded to that the voluntary factor is absent.

The simplest view to take of voluntary micturition is the following: The will causes the abdominal muscles to contract, and the increased pressure on the bladder so produced is the signal for the reflex to occur. It is further probable that the mere thought of micturition may influence the sacral vesical center, and heighten its sensitiveness. This certainly is the case in the neighboring center for the erection of the penis. Erection can be evoked as a reflex act, yet it is a matter of experience that it also takes place as a result of the emotions. If urine is voided too frequently, the cause may be (1) peripheral, as in inflammation of the bladder. Here the organ is unduly sensitive to the pressure of fluid, and (2) central, as in cases of fear and excite-

ment; here the sensibility of the vesical center is heightened. In children where control of the vesical center is often not fully established while they are young, frequent and involuntary micturition may occur.

THE SYMPATHETIC SYSTEM

Allusion has frequently been made to sympathetic nerves. These nerves govern the processes in the body over which we have no voluntary control. They innervate cardiac muscle, the plain muscle in the walls of blood vessels, and in the walls of other contractile viscera such as the stomach and intestine, the bladder, and the organs of generation. Secretory nerve fibers also come into the same category.

The sympathetic system proper consists of a chain of ganglia or collections of nerve cells, situated on each side of the vertebral column. These ganglia correspond roughly with the spinal segments; the uppermost is called the superior cervical ganglion, and the next the inferior cervical ganglion; these are the only two ganglia in the cervical regions in the dog; in man there is a middle cervical ganglion in addition. The inferior cervical ganglion is connected to the first thoracic ganglion, a large ganglion sometimes called the ganglion stellatum, by fibers, some of which go in front of, and others behind the subclavian artery; this ring around the artery is called the annulus of Vieussens; after this the correspondence of the ganglia to the spinal nerve roots is more exact, and we finally reach the ganglion at the end of the chain, the ganglion coccygeum.

All these ganglia (with the possible exception in some animals of the inferior cervical ganglion) send bundles of nerve fibers to the spinal nerves, and the communicating strands between the ganglia and the

spinal nerves are termed the rami communicantes. The white rami consists of medullated fibers of small diameter; the gray rami consists mainly of non-medullated nerve fibers.

The sympathetic chain, then, is a system of ganglia longitudinally arranged, and these ganglia are called the vertebral or the lateral ganglian.

In connection with the lateral chain are other outlying ganglia, such as the semilunar ganglion, from which the coeliac plexus takes origin; the superior mesenteric ganglion, and the inferior mesenteric ganglion, from which the hypogastric nerve takes origin. These outlying ganglia are called the collateral or the prevertebral ganglia. These differ from the lateral ganglia in not sending any fibers back to the spinal nerves; their fibers pass onward to the thoracic, abdominal, and pelvic viscera.

Finally, there are ganglia situated in the walls of the organs themselves, as, for instance, those in the heart wall, and those in the plexuses of the wall of the alimentary canal (the plexuses of Auerbach and of Meissner). By some, these ganglia are included with the collateral ganglia, but it appears better for descriptive purposes to speak of them as Gaskell does, as a third group, and name them the terminal ganglia.

The sympathetic system thus consists of three sets of ganglia with strands connecting them together, and all come into ultimate connection with fibers that leave the spinal cord.

There is, however, another set of ganglia which are related anatomically in a similar way to some of the cranial nerves, and physiologically with the involuntary muscles and glands in the head region as well as with some of the thoracic and abdominal organs. Thus we

have the ciliary ganglion in connection with the third cranial nerve; then there are such ganglia as the sphenopalatine, otic, and submaxillary, in connection with other cranial nerves.

It has been considered wise not to extend the term sympathetic to these, but to include both them and the sympathetic system under one common term, and Langley's suggestion that this word should be autonomic has been very generally adopted. The word indicates that they possess a certain power of self-government, and are to some extent, at any rate, independent of the central nervous system.

The impulses that pass to the involuntary musculature of the body arise in the central nervous system, and travel to the ganglia of the autonomic system by means of fine medullated nerve fibers; the diameter of these fibers varies from 1.8 to 3.6 u (=micro-millimeter); the fibers therefore contract with the motor fibers which pass to voluntary muscles; the diameter of these being 14 to 19 u. There is a further contrast in the two cases; the motor fibers to voluntary muscles pass uninterruptedly from the brain or cord until they terminate in the end-plates of the voluntary muscles. The autonomic fibers, on the other hand, terminate by arborizing around cells in one or other of the autonomic ganglia, and from the ganglion cells a fresh relay of nerve fibers carries on the impulse to the involuntary muscles. There is thus an extra cell-station or synaptic junction outside the central nervous system altogether. The autonomic path, in other words, consists of two neurons; one from the central nervous system to the ganglion, and a second from the ganglion to the peripheral tissue. The first axon is termed the pre-ganglionic fiber; the second, the post-ganglionic fiber. The pre-ganglionic

fibers are fine medullated ones, and the post-ganglionic fibers are usually non-medullated ones, but there are exceptions to this rule.

The small medullated or pre-ganglionic fibers arise from the following four regions of the central nervous system.

1. From the mid-brain, issuing therefrom by the third cranial nerve (motor oculi).
2. From the medulla oblongata, issuing therefrom in the seventh (facial), ninth (glosso-pharyngeal), tenth (vagus), and eleventh (spinal accessory) nerves.
3. From the thoracic region of the spinal cord, issuing therefrom in the anterior roots of the spinal nerves and passing from these by the white rami communicantes to the sympathetic ganglia. These occur in all the nerves from the first or second thoracic, as far down as the second, third, or fourth lumbar nerves.
4. From the sacral region of the spinal cord, issuing therefrom by the anterior roots of the second, third, and fourth sacral nerves, and thence passing by white rami communicantes to sympathetic ganglia; these fibers supply the descending colon, rectum, anus, and urino-genital organs in the pelvis, and they constitute the nervi erigentes.

It will be noticed that in the spinal district white rami communicates only occur in certain regions; but all the spinal nerves have gray rami which consist of post-ganglionic fibers returning to the spinal nerves for distribution to the blood vessels of the body wall, to the muscles which erect the hairs (pilo-motor nerves) and to the sweat glands of the skin.

The cell-station of any particular pre-ganglionic fiber is not necessarily situated in the first ganglion to

which it passes; the fibers of the white ramus communicans of the second thoracic nerve, for instance, do not all have their cell-stations in the second thoracic ganglion, but may pass upwards or downwards in the chain to a more or less distant ganglion before they terminate by arborizing around its cells. It therefore follows that fibers that leave any given spinal nerve by its white ramus, do not necessarily return as post-ganglionic fibers by the gray ramus to the same spinal nerve.

Furthermore, there are many fibers of the white rami which enter the lateral chain of ganglia and pass through them without communicating with their cells at all, and never return to the spinal nerves by gray rami. They pass out of the lateral chain either to collateral or even terminal ganglia before reaching their cell-stations, whence they emerge as post-ganglionic fibers. This is the case for the sympathetic supply of the blood vessels and of involuntary muscular fibers of the thoracic, abdominal, and pelvic viscera, and is therefore true for such important nerves as the cardiac accelerators, the splanchnics, and the nervi erigentes.

The next question that arises is, how have all these facts been ascertained; for it is obviously impossible to follow the individual fibers with the microscope, and still less with the naked eye. The method above all others which has proved successful in solving the problem is the nicotine method, originally introduced by Langley and Dickinson, and employed since by Langley mainly in conjunction with H. K. Anderson.

The *Nicotine Method*.—Nicotine in small doses paralyzes nerve cells, but not nerve fibers. Before the paralytic effect of nicotine comes on, it excites the nerve cells, and this in the case of the blood vessels

causes a general constriction of the arterioles, and a consequent rise of arterial pressure. It is still a matter of uncertainty whether the drug produces these effects on the nerve cells themselves or on the terminal arborizations (synapsis) of the fibers that surround them, or on receptive substances either in the cells or present at the synaptic junctions. But whichever of these modes of action is the correct one, the main result is the same; a nervous impulse which reaches a ganglion by a preganglionic fiber cannot get across to the corresponding post-ganglionic fiber if the animal is poisoned with nicotine. Stimulation of the anterior nerve-roots, or of the white rami no longer produces movements of the involuntary muscular tissues, because the paralyzed cell-stations act as blocks to the propagation of the impulses. If, however, post-ganglionic fibers are stimulated, the usual effects (for instance, constriction of blood vessels, erection of the hairs, etc.) take place. If instead of injecting nicotine into the circulation, and so producing a general effect, the nicotine is painted over one or more ganglia, there will be a block in those fibers only which have their cell-stations in those particular ganglia. By patiently examining all the ganglia in this way in turn, stimulating the fibers that enter it and those that leave it, Langley and his colleagues after years of work, have been successful in localizing the cell-stations on most of the autonomic paths in the body.

1. The autonomic nerve fibers which arise from the mid brain. These emerge by the third nerve; the preganglionic arising from the cells of this ganglion run in the short ciliary nerves to supply the intrinsic muscles of the eyeball (sphincter iridis and ciliary muscle).

2. The autonomic nerve fibers which arise from the

medulla oblongata. These emerge by the following nerves:—

(a) Seventh and ninth nerves. These supply the blood vessels with vaso-dilator fibers and also the secreting glands in the nose and mouth region. Many of these fibers (for instance, those in the chorda tympani) get bound up with branches of fifth nerve, and are distributed with them. The ganglia on the course of these fibers are the spheno-palatine, otic, submaxillary, and sublingual ganglia.

(b) Tenth and eleventh nerves. These are distributed by the branches of the Tenth or vagus nerve to the œsophagus, stomach, and part of the intestine, to the bronchial muscles, to the heart, and to the gastric and pancreatic secretory mechanism. Here our knowledge of the localization of the cell-stations is not so exact as it is in other parts; some of the fibers appear to have their cell-stations in the ganglion on the trunk of the vagus, but in most cases they do not become post-ganglionic until the terminal ganglia in the walls of the various organs mentioned are reached.

3. The autonomic fibers which arise from the thoracic region of the spinal cord. These constitute the best known of the autonomic fibers, and we may describe them according to their distribution under the following two headings:

(a) The white rami leaves the spinal nerves and find their cell-stations in lateral ganglia, returning by the gray rami for distribution to the involuntary muscular tissue and glands in the body walls and skins. Thus in the lateral chain of ganglia we find the cells on the course of the pilo-motor nerves, or the nerves to the sweat glands, possibly of the splenic nerves, and last

but not least, of the vaso-constrictors of the head, limbs, and body wall. Indeed, at one time, Gaskell suggested that the lateral chain should be called the chain of vaso-motor ganglia. In general terms the cell-stations are situated in ganglia that correspond with the various spinal segments; those for the lower limbs, for instance being further down the chain than those for the trunk and upper limb. The vaso-constrictor fibers destined for the head, ascend the cervical sympathetic and do not reach their cell-station until they arrive at the superior cervical ganglion.

(b) The pre-ganglionic fibers traverse the lateral ganglia, and emerge still as pre-ganglionic fibers, which find their cell-stations in more or less outlying ganglia (collateral or terminal). We have already taken the splanchnic nerve as one example of this mode of distribution; the nerve contains inter alia the vaso-constrictor fibers, and viscero-inhibitory fibers of the abdominal organs. The hypogastric nerve arises in a similar way from the inferior mesenteric ganglion and joins the pelvic plexus. The medullated pre-ganglionic fibers of this nerve arise from the upper lumbar nerve roots.

4. The autonomic nerve fibers which arise from the sacral region of the spinal cord. The pre-ganglionic fibers emerge in the white rami of the second, third, and fourth sacral nerves. They pass through the sacral ganglia of the lateral chain without forming connections with any cells there, and they pass on as the nervus erigens, or pelvic nerve, to join the pelvic plexus. The fibers of this nerve supply vaso-dilator fibers to the external generative organs (whence its name), to the rectum and anus, and motor fibers to the musculature

of the descending colon and rectum, and have their cell-stations in the small scattered ganglia of the pelvic plexus, or in terminal ganglia in the walls of the viscera they supply.

Looking at the involuntary muscles for a moment from a rather different point of view, we see that they (or most of them) differ from the voluntary muscles in being supplied by two sets of nerve fibers with opposite functions. In the case of the heart, we have an accelerator set which course through the sympathetic, and an inhibitory set which course through the vagus. In the case of the blood vessels, we have an accelerator set called vaso-constrictors, and an inhibitory set called vaso-dilators. In the case of the contractile viscera we have also viscero-accelerator and viscero-inhibitory, which respectively hasten and lessen their peristaltic movements.

Adopting Gaskell's nomenclature, we may term the accelerator groups of nerves katabolic, because they increase the activity of the muscles they supply, bringing about an increase of wear and tear and an increase in the discharge of waste materials, the products of their activity. The inhibitory nerves, on the other hand are anabolic, as they produce a condition of rest in the tissues they supply, and so give an opportunity for repair, or constructive metabolism.

As a general rule, though there are exceptions to it, the cell-stations of the anabolic nerves are in collateral or terminal ganglia, whereas the cell-stations for katabolic nerves are in the lateral chain, or in some cases in collateral ganglia.

Post-ganglionic fibers are more numerous than pre-ganglionic fibers, and this brings us to the main object served by the ganglia on the autonomic nerves. Nature

has, as it were, before her the problem of supplying with nerves the vast mass of muscles in the body, and the space at her command in the various exits from the cranium and spinal canal does not allow of more than a comparatively small outflow from the central nervous system.

The difficulty is met to some extent by the branching of the outflowing nerve fibers, and in the case of the voluntary muscles this appears to be sufficient. The most striking example of this can be seen in the electrical organ of the Malapterurus, where the millions of its subdivisions on each side of the body are all supplied by the branches of a single axis-cylinder process originating from a single giant nerve cell in the brain.

But in the case of the involuntary muscular tissue there is an additional means of distribution, for each fiber that leaves the central nervous system arborizes around a number of cells in the autonomic ganglia, and thus the impulse is transferred to a large number of new axis-cylinder processes.

The name sympathetic was originally bestowed on the system of nerves we are considering, because the ganglia were believed to be the centers for reflex actions, or sympathetic actions as they were formerly designated.

During their work on autonomic nerves Langley and Anderson have once more investigated this ancient question, but the only instances where such a thing seemed possible were the following: When all the nervous connections of the inferior mesenteric ganglion are divided except the hypogastric nerves, stimulation of the central end of one hypogastric causes contraction of the bladder, the efferent path to which is the hypogastric nerve. But the action is not truly reflex; it is

caused by the stimulation of the central ends of motor-fibers which issue from the spinal cord, and which after passing through the ganglion send branches down each hypogastric nerve. The experiment is in fact similar to Kuhne's gracilis experiment. They also observed an apparent reflex excitation of certain nerves supplying the erector muscles of the penis (pilo-motor nerves) through other sympathetic ganglia; but this is explicable in the same way.

It certainly is the case that under normal circumstances the centers for reflex action are in the central nervous system. But there do appear to be some conditions in which it is possible for ganglia to assume this function. The recovery of vaso-motor tone, and of tone in certain viscera after destruction of extensive tracts of the spinal cord, or the persistence of peristaltic action in the intestine after cutting through all its nerves, are cases in point. Such action forms, in fact, the chief justification for the adoption of the new term, autonomic.

Up to the present point, we have only considered the efferent fibers of the autonomic nerves. No survey of the autonomic system will, however, be complete which does not include an amount of the afferent fibers. This will not occupy much space, because our information on this side of the subject is so scanty.

The "vegetative" functions of the body are carried out independently of volition, and under normal circumstances they also cause no sensations. In pre-anaesthetic days, surgeons discovered that the viscera possess no sensibility in the ordinary sense; they may be handled and cut without producing pain; and, with the exception of the œsophagus, they are insensitive also to heat and cold.

Still, under abnormal conditions we become conscious of their activity, especially if it is excessive, as for instance in the very severe pain which the various forms of colic give rise to. But even under these circumstances there is great difficulty in accurately localizing the pain.

In the autonomic system, the afferent or sensory fibers are much less numerous than those which are efferent. This has been ascertained by cutting the anterior nerve roots which communicate with an autonomic nerve; the efferent fibers will degenerate peripherally, but the sensory fibers will remain intact, and the relative number of healthy and degenerated fibers can then be counted. Thus in the splanchnic and hypogastric nerves about one-tenth of the fibers are found to be sensory; and in the pelvic nerve about one-third of the total fibers are sensory.

The gray rami contain few if any sensory fibers; excitation of their central ends produces neither pain nor reflex action; and the same is true for the cervical sympathetic.

On the other hand, excitation of the central ends of the white rami produces reflex movements, especially in involuntary muscles, as is evidenced by a rise of blood pressure due to constriction of peripheral arteries; this is especially the case with white rami connected with thoracic and abdominal viscera.

It is therefore deduced from this that the sensory autonomic fibers enter the central nervous system by the white rami, but whether they come into relationship with the cells of either sympathetic or spinal ganglia is very uncertain. Possibly the cells of origin are within the spinal cord itself. In the cranial region we have

some information especially in connection with the vagus nerves of the existence of afferent fibers.

Referred Pain. Localization of painful or uncomfortable feelings arising from disorders of internal organs is always very difficult. But they are associated with pains in the skin, and this referred pain, as it is called, often plays an important part in ascertaining the position of internal maladies. Pains arising from intestinal irritation are referred to the skin of the lumbar region in the area supplied by the lower thoracic nerves; pains originating in the stomach are referred to an area of skin above this at the lower margin of the ribs, those from the heart to the shoulder region, and so forth.

Each viscus appears to be correlated with a definite patch or band of skin; this may even be tender on pressure. Ross' suggestion that the pain in such case is referred by sensory cutaneous fibers ending in the same segments of the cord as do the efferent fibers from the viscera in question, and has been placed beyond doubt by the subsequent work of Mackenzie and of Head.

CILIARY MOTION OF EPITHELIUM

Ciliary motion is independent of the will, and of the influence of the nervous system. It may continue for several hours after death or removal from the body, provided the portion of tissue under examination be kept moist. Its independence of the nervous system is shown also in its occurrence in the lowest invertebrate animals, which are unprovided with anything analogous to a nervous system. The vapor of ether or chloroform and carbon dioxide arrest the motion, but it is renewed on the discontinuance of the application. The movement ceases when the cilia are deprived of oxygen,

although it may continue for a time in the absence of free oxygen, but is revived on the admission of this gas. The contact of various substances, e.g., bile, strong acids and alkalis, will stop the motion altogether, but this depends on destruction of the delicate substance of which the cilia are composed.

Ciliary motion of epithelium is caused directly by changes in the cells to which the cilia is attached; since when the latter are cut off from the cell, the movement ceases, and when severed so that a portion of the cilia are left attached to the cell, the attached and not the severed portion of the cilia continue the movement. (This action is fully studied in the chapter on Cells.)

NUTRITION OF EPITHELIUM

Epithelium has no blood vessels; it is nourished by lymph. When the blood is circulating through the thin-walled small blood vessels in the tissues beneath the epithelium, some of its fluid constituents escape. This fluid is called *lymph*. It penetrates to all parts of the cellular elements of tissues and nourishes them. In the thicker varieties of the irregular minute channels between the cells, enables the lymph to soak more readily between the cells than it would otherwise be able to do. Epithelium is also destitute of nerves as a rule. But in stratified epithelium, particularly that covering the cornea at the front of the eye and in the deeper layers of the epidermis, a plexus of nerve fibrils is found. (References from Halliburton.)

CHAPTER X

THE SPINAL CORD AS AN ORGAN OF CONDUCTION

THE functions of the spinal cord fall into two categories: Functions of the gray matter, which consists in the conversion of afferent into efferent impulses (reflex action); and functions of the white matter which are those of *conduction.*

The fibers of the spinal cord consists of three main groups; those are: (1) the *association tracts,* which connect together different segments of the cord and thus bring about co-ordination of the impulses, which leave it at various levels, in relationship to the impulses which enter the cord either below or above any particular region; (2) the *efferent* rejection fibers, which connect the cord with the different parts of the brain above it. The main motor path, the pyramidal tract, comes into this category; and after our full description of its course, we need not do more here than remind the reader that it originates from the giant pyramids of the motor area of the cortex, and that its fibers cross to the opposite side of the spinal bulb; from the gray matter in which it terminates in the cord, the impulse is continued onward, until in the end it reaches the muscles via the fibers which leave the cord in the anterior nerve roots; (3) the afferent projection system of fibers; these primarily enter the cord by the posterior spinal nerve roots. The impulses which these convey enter (a) the spinal gray matter, (b) the cerebellum, and (c) the cerebrum, the seat of consciousness. (See Chapter on The Psychical Processes.)

It is these sensory tracts which are the most complex, not only on account of the cell-stations in their course, but also on account of the difficulty of determining in animals the different kinds of sensations which are present in health, or which may be absent after injury to various tracts. It is, however, certain that ultimately, so far as the cerebrum is concerned, crossing occurs somewhere, so that each hemisphere is related to the opposite half of the body, not only in regard to motion but in regard to sensation also. The main difficulty of investigation has been to determine exactly where the crossing occurs; in man especially, many of the impulses cross shortly after their entry into the cord, and then travel up to the higher centers by paths on the opposite side of the cord to that which it enters. In such investigations on man, various injuries to the cord have to be carefully studied, and it is such careful study that has led to this conclusion.

For over fifty years, physiologists, stimulated by the work of Brown Sequard, have attempted to trace the upward paths of afferent impulses through the spinal cord. By experiments on animals, the secondary ascending degenerations which follow injury can be followed with exactitude, and traced into bulb, cerebrum, cerebellum, or other parts. But even though some animals may be long under observation, they cannot tell us, and we can only with difficulty and ill-success guess, how their sensations are affected by the lesion.

On the other hand, the clinical observer may expend much time and trouble in determining the nature of the loss of sensation, but it is usually impossible to verify the anatomical position and nature of the lesion. In many cases where a microscopical examination has been made, the disease has been of a progressive nature, or

the patient has died from complications, which detract from his suitability to an examination of this kind.

Nevertheless, by a combination of the experimental and clinical methods, we have now arrived at some accuracy on these points, and it is impossible to overestimate in this direction the value of the psycho-physical examination of patients which has within the last few years been made by Head, Rivers, Sherren, and Tanzi.

In order, however, to examine the sensations of a patient, it is necessary to know first how to classify the sensations which are the result of cutaneous stimulation. To do this, we must somewhat anticipate what should be more fully discussed under Cutaneous Senses. It has been proved that, scattered over the external surface of the body, are a number of spots, some of which are more susceptible to one form of stimulus than others. The spots are of four kinds; known as touch spots, pain spots, heat spots and cold spots, and these correspond to the four kinds of sensation which we experience as the result of cutaneous excitation. They correspond to different kinds of end-organs in the skin, and the impulses are carried to the central nervous system by different groups of fibers.

Dr. Head found, from an experiment he made by cutting a sensory cutaneous nerve in his own arm, that although the patch of skin supplied by the nerve was entirely destitute of sensation, the underlying parts were still sensitive to pressure and to pain. These deep sensations are subserved by nerve fibers which are distributed with the muscular nerves. It is by means of the sensory nerves of muscles, tendons, and joints that we are aware of the position of our limbs, and the extent of muscular contraction.

After a time true cutaneous sensation returned when the severed nerve regenerated, but it was not until many months elapsed that sensation was as sharp and as accurately localized as it was before the nerve had been cut. The first sensations that returned enabled Head to feel pain, to distinguish large differences of temperature, and to localize the position of a touch somewhat inaccurately. Head terms such imperfect sensations *protopathic*. The ability to localize accurately, to distinguish small differences of temperature and the finer distinctions generally of cutaneous sensations, returned later, and are spoken of as *epicritic*. We may thus divide the main sensations forming from the periphery of the body into deep and cutaneous; and the cutaneous sensations into protopathic and epicritic.

The other classifications into sensations of touch, heat, cold, and pain, cuts across the first; thus we may have pain that is of deep or of cutaneous origin; we may have temperature sensations which are both rough or protopathic, and accurate or epicritic; and we may feel pressure and localize it by means of the cutaneous sense proper, or by the stimulation of the sensory nerves in the deeper structures. Whether different nerve fibers are concerned in the transmission of the protopathic and epicritic impulses is a matter of doubt. It is quite possible that the same fibers may be concerned in the transmission of both.

Diseases of the spinal cord in man usually are widespread and affect many tracts; the disorders of muscular paralysis and of sensation thus produced will therefore be complex. The more limited the lesion, the fewer tracts will be affected, and such conditions are, therefore, more suitable with these localized lesions or sections of tracts which can be performed on animals.

The operation of hemisection in an animal produces paralysis of the same side of the body below the injury. So it is in a man in whom disease has produced an interruption of the pathways on one side only of the cord. But such an animal or man (and the observation is more accurate in man) will not have lost all sensation on the same side; tactile discrimination, and the motorial sense will have largely disappeared, but sensations of pain, of heat, and of cold will still remain, because the tracts which convey such impulses cross over in the cord at varying levels after entering it, and therefore any loss in such sensations will occur on the opposite side to that which it injured.

It was no doubt absence of correct knowledge on this question that led Schiff to imagine that impulses translated by the brain, as sensations of temperature and pain, traveled up by the gray matter, and not by the posterior columns. It certainly is the case that in the condition called syringomyelia (a disease of the gray matter of the cord), sensations of heat, cold, and pain are lost, but this is due to the disease cutting through the crossing fibers which convey the impulses in question. Head has pointed out that disease strictly limited to the gray matter does not produce loss of any kind of sensation, except by interfering with those paths which pass through its substance.

We have seen that afferent impulses pass into the cord by peripheral nerves (the primary or peripheral level) in certain combinations from the protopathic, epicritic, and deep systems. In the spinal cord these are sorted out and travel up in new combinations, and it is possible that before they finally reach the cortex a fresh sorting may take place in higher cell-stations before they ultimately arrive at the seat of consciousness. The first

arrangement occurs at the *secondary level,* that is on the entrance into the cord, and a further sorting at the *third level,* but of this little is known at present. Head's work so far has been chiefly concerned with the rearrangement at the second level, as derived from a study of the spinal cord disease.

We may make a rough comparison of what occurs, to what takes place in the correspondence which flows in from all quarters to a busy man, such as a Secretary of State. The letters will come from all quarters, and deal with numerous topics; some will be private letters, some will be advertisements, some will be official, some begging letters and so forth. This mass of correspondence will be sorted out by minor officials, the advertisements and the begging letters will probably never reach the busy officer of State, and he will therefore not be conscious of their existence unless he examines the waste paper basket. But the private letters and the official letters will be sorted into separate lots, whether they come from England or farther countries, and these ultimately reach his eye. In the same way, the impulses which give rise to pain, whether from cutaneous or deep structure, will all be combined and travel up one path. Those due to heat or cold, whether protopathic or epicritic, in other paths; those which are tactile or motorial, in another. And so a localized spinal lesion may interrupt all the fibers subserving the sensation of heat without interfering with those which underlie sensations of cold and so forth.

Tactile, painful, and thermal impulses, and those associated with tactile localization, cross in their passage through the spinal cord at varying levels soon after entrance. But the sensory impulses which underly the recognition of passive position and movement, and finer

tactile discrimination, do not cross within the limits of the spinal cord; they pass up the posterior column on the side of entrance, and so reach the gracile and cuneate nuclei of the bulb, and it is the fibers which arise from the cells of these nuclei which cross in the decussation of the fillet.

The rapidity with which the sensory impulses cross to the opposite side varies greatly. Some, such as those associated with pain, heat, and cold, cross over in the space of five or six spinal segments. With tactile impulses the crossing is evidently less rapid; but until the crossing is completed there will obviously be two channels, one on each side of the cord, open for tactile impulses; and such a double path will be shorter for the impulses which cross more rapidly; and finally, as just stated, the impulses associated with position, movement and tactile discrimination have only one path in the cord, as the decussation does not take place until the bulb is reached; hence a hemisection of the cord, or of one posterior column, will abolish these forms of sensibility from the parts below the lesion, on the same side of the body as the lesion.

Painful impulses from the skin arriving in the cord from protopathic fibers pass into the second level at the point of entry, and rapidly cross over to the other side. Fibers of the deep system running with the muscular nerves and carrying impulses also of a painful kind from the same part of the body do not necessarily enter the cord by the same posterior roots as those carrying cutaneous painful stimuli. Thus more than one segment of the cord is required before all painful impulses from any one part of the body can be gathered together and recombined. This is the reason why, in a local lesion in the cord, there may be a want of

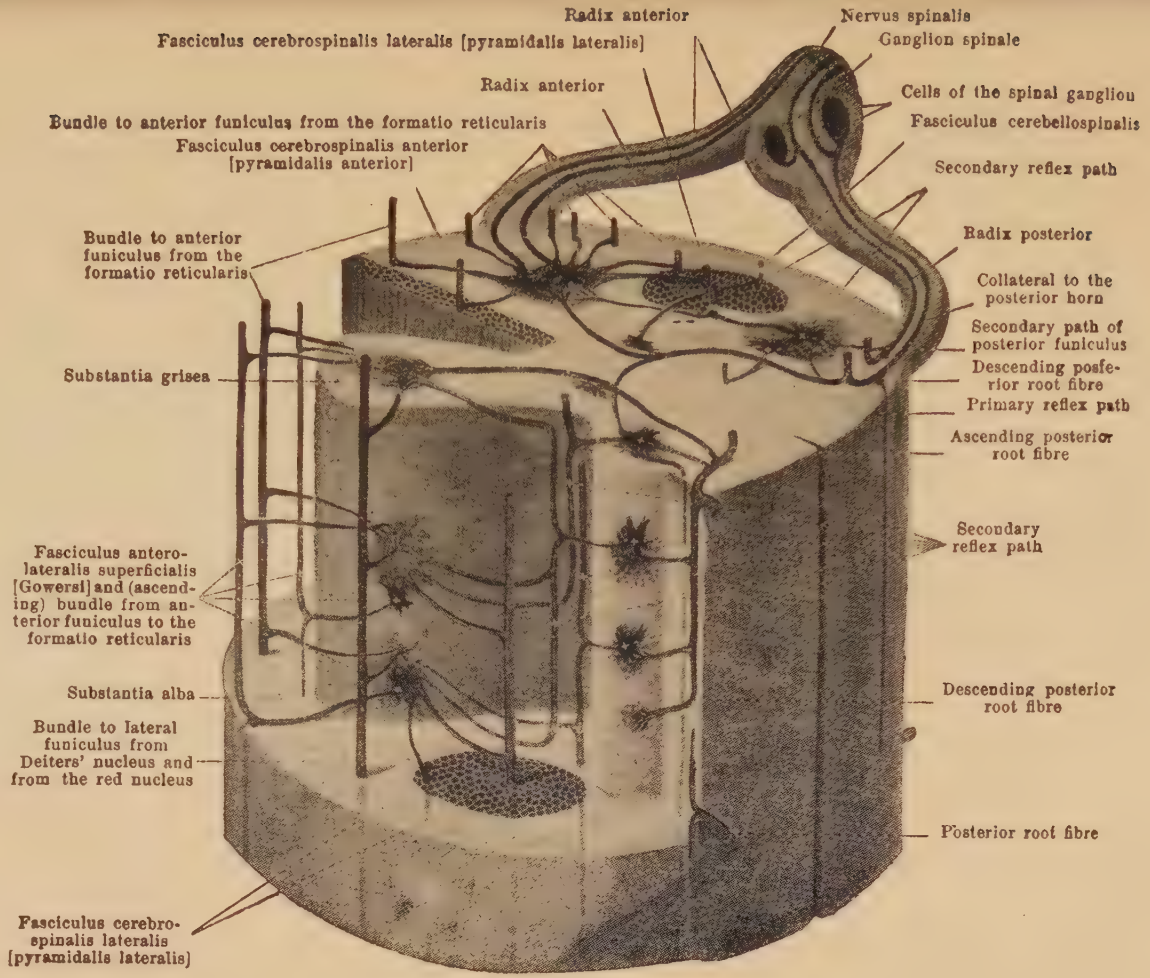
correspondence between the extent of cutaneous and deep *analgesia* (loss of sensation to pain).

Up to this point we have only considered the sorting out of those impulses which reach the cerebrum and thus rise into consciousness. In addition to this there is another group of impulses which never rise into consciousness at all, and although they are afferent, they are therefore not sensory.

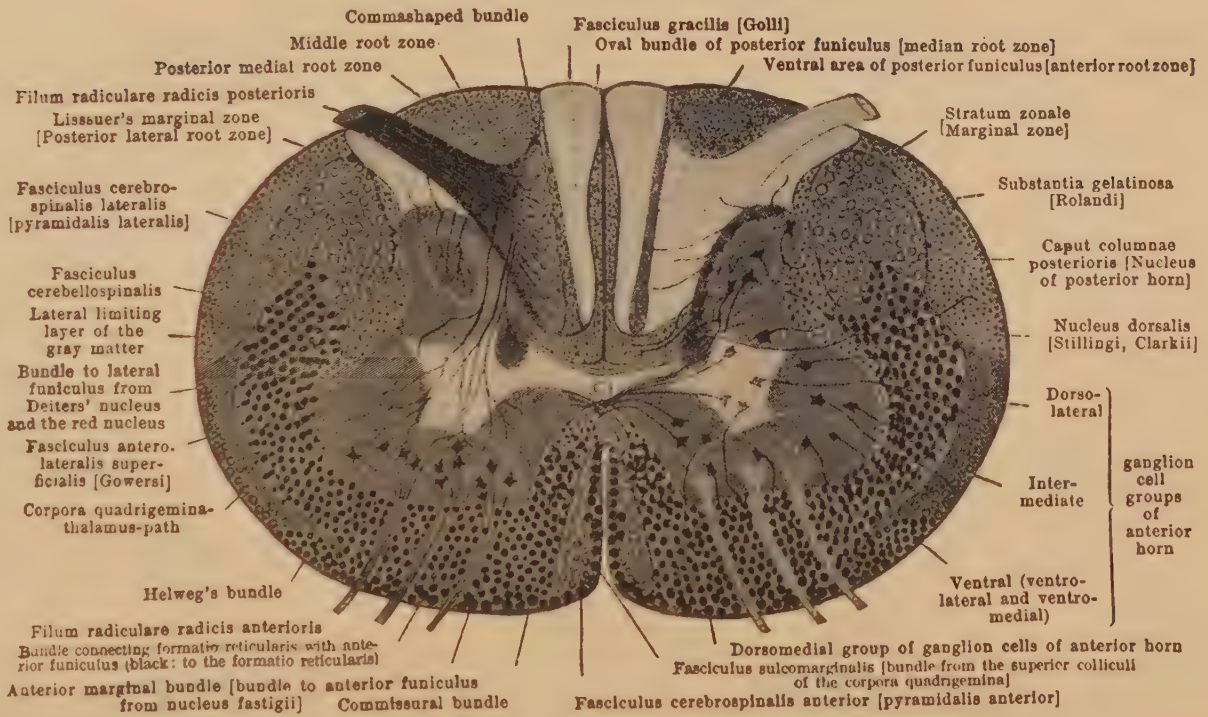
Our previous illustration of the correspondence of a busy man may help us again in understanding this. His clerk sorts his letters, and those of a certain kind (circulars and the like) will probably never reach him at all. So it is with afferent impulses; the primary sorting is into sensory and non-sensory; the sensory impulses are again sorted into those of touch, pain and temperature; the non-sensory impulses are those mainly destined for the cerebellum, and reach it by the cerebellar tracts. These travel up the cord on the side of entry, and reach the same side of the cerebellum. This explains the delay in the crossing of the sensory of the sensory impulses which subserves the sense of position and movement and tactile discrimination, a crossing which, as we have seen, does not occur until the bulb is reached. It is impulses from the joints and muscles which are specially important for the cerebellum to enable it to carry out its functions of equilibration and co-ordination of muscular movements. These impulses are non-sensory, but they are carried by fibers which originate as collaterals from those which carry the true sensory impulses of the same nature to the cerebrum. This group of fibers therefore remain in the cord on the side of entry, in order to be in the neighborhood of the cerebellar tracts; the impulses reach the cerebellar tracts with the inter-mediation of a cell-station

in Clarke's column. When the tract conveying what we may term the motorial sensations to the cerebrum has ministered in this way to the needs of the cerebellum, there is nothing to prevent it following the example of the other tracts, so when the spinal cord is passed and the bulb reached, crossing of these fibers occurs in due course.

To sum up—the spinal cord is the seat of the transmutation of most of the impulses of the first or peripheral level into those of secondary level of the afferent projection system. This recombination takes place on the same side as that by which the impulses enter the cord. The secondary paths for sensory impulses then cross with greater or less rapidity, so that ultimately all except those subserving the sence of position and movement and tactile discrimination have passed to the opposite side within the limit of the spinal cord; and those which do not cross in the cord do so after reaching the nuclei of the posterior columns. At the same time, within the spinal cord afferent impulses become separated into sensory and non-sensory, and the latter are exemplified by those which reach the same side of the cerebellum by the cerebellar tracts.


Radix anterior
Nervus spinalis
Fasciculus cerebrospinalis lateralis [pyramidalis lateralis]
Ganglion spinale
Radix anterior
Cells of the spinal ganglion
Bundle to anterior funiculus from the formatio reticularis
Fasciculus cerebellospinalis
Fasciculus cerebrospinalis anterior [pyramidalis anterior]
Secondary reflex path
Radix posterior
Bundle to anterior funiculus from the formatio reticularis
Collateral to the posterior horn
Secondary path of posterior funiculus
Substantia grisea
Descending posterior root fibre
Primary reflex path
Ascending posterior root fibre
Secondary reflex path
Fasciculus antero-lateralis superficialis [Gowersi] and (ascending) bundle from anterior funiculus to the formatio reticularis
Substantia alba
Descending posterior root fibre
Bundle to lateral funiculus from Deiters' nucleus and from the red nucleus
Posterior root fibre
Fasciculus cerebro-spinalis lateralis [pyramidalis lateralis]

Conduction Paths in the Central Nervous System.


Commashaped bundle
Middle root zone
Posterior medial root zone
Filum radiculare radicis posterioris
Lissauer's marginal zone [Posterior lateral root zone]
Fasciculus cerebrospinalis lateralis [pyramidalis lateralis]
Fasciculus cerebellospinalis
Lateral limiting layer of the gray matter
Bundle to lateral funiculus from Deiters' nucleus and the red nucleus
Fasciculus anterolateralis superficialis [Gowersi]
Corpora quadrigemina-thalamus-path
Helweg's bundle
Filum radiculare radicis anterioris
Bundle connecting formatio reticularis with anterior funiculus (black: to the formatio reticularis)
Anterior marginal bundle [bundle to anterior funiculus from nucleus fastigii]
Commissural bundle
Fasciculus gracilis [Golli]
Oval bundle of posterior funiculus [median root zone]
Ventral area of posterior funiculus [anterior root zone]
Stratum zonale [Marginal zone]
Substantia gelatinosa [Rolandi]
Caput columnae posterioris [Nucleus of posterior horn]
Nucleus dorsalis [Stillingi, Clarkii]
Dorsolateral
Intermediate
Ventral (ventrolateral and ventromedial)
ganglion cell groups of anterior horn
Dorsomedial group of ganglion cells of anterior horn
Fasciculus sulcomarginalis [bundle from the superior colliculi of the corpora quadrigemina]
Fasciculus cerebrospinalis anterior [pyramidalis anterior]

CHAPTER XI

SYNAPSES

WE have shown already that chemical actions are influenced by increase or decrease of temperatures, and that a ray of light or electronic energy by its absorption in matter can change its velocity or vibration so as to emanate or act as an infra-red ray or heat-ray which has certain thermic effects. We will explain now how the electric or electronic energy of the body in its courses and impulses through nerves, will change its velocity or vibration according to its conductor, circuit, or substance encountered; these impulses may become thermic-rays or vibrations which in their turn cause the chemical changes in the body. It must be easy to understand after our discourse in specific nerve functions in the human system that the atmosphere, sunlight, magnetic stresses of the earth, the respiratory function, and nutrition are the most important factors for the maintenance of the electric equilibrium in our body.

This leaves, however, two important factors to be explained. One is the conscious and subconscious mental process or intelligence, which we are willing here to classify under the heading of psychology and of which we know too little to even discuss, except that part of it that shows undisputable evidence by its physical connection with the brain, (see chapter on physical process) and the other is the internal regulating mechanism which is revealed to us through the close study of nerve function and its construction. In this later subject we have ample material for some startling discoveries.

The newly acquired knowledge of the action of radio-energy, construction of radio-circuits, vacuum tubes, transformers and condensors, leads us to startling conclusions, when we compare the nerve circuits and their construction with these.

In studying the illustrations in this chapter the most striking feature in the presence and construction of *Synapses.* We find that at every possible branch or junction these synapses are present and we also know that there is no true anostosis between nerve cells. In other words, there is no true electrical connection or contact between the different nerve fibers such as would be required for the conduction of a direct current. What is their purpose and action? Dr. Crile has likened them to electrical switches which open or close to either make or break connections in order to make possible the connection and the termination of nerve impulses according to their purpose. This seems logical on superficial conclusion but it would also necessitate the presence of an intelligent, conscious or subconscious will, on the part of these synapses or switches. This, however, seems unreasonable and leaves therefore this theory as a physical explanation in some doubt.

The synapses as suggested by Sherrington, may be endowed with special properties. They might restrain, diffuse, bank up pressure, restrict the movement of ions, accumulate electric charges, support a double electric layer, alter in shape and surface tension with changes in difference in potential, alter in difference of potential with changes in surface tension, or in shape, or intervene as a membrane between dilute solutions of electrolytes of different concentrations or colloidal suspensions with different signs or charges.

Cells in their electro-chemical oxidation may also produce heat; this heat, through the synapses, may set up an electro motor current (thermo-couple effect) in the afferent nerves; this current can now be used by the nervous system according to the electro-chemical demands of other organs; it can also be sent to the brain, to be used and re-directed for motor impulses, it can also be utilized to again generate heat through the same reverse action of synapses.

In fact, the synapsis in the nervous system might be construed to be the electrical intelligence of the nervous system and no doubt, all purely reflex and automatic functions in the system, which do not require the directing power of the brain, or intelligence might be said to be governed and controlled by this most marvelous and ingenius tuner or condenser system, which we term synapses.

Let us now consider

THE LAW OF AXIPETAL CONDUCTION

A general law has been laid down by van Gehuchten and Cajal, that all nerve impulses are axipetal, that is, they pass towards the attachment of the axon, by which they leave the body of the cell. In other words, the direction of an impulse is towards the body of the cell in the dendrons, and away from it in the axon. When we further consider that every nervous pathway is formed of a chain of cells, and that the impulse always takes the "forward direction," we see that there is what we may compare to a valved action which permits the passage of impulse in one direction only. The synapses are the situations of these so-called valves.

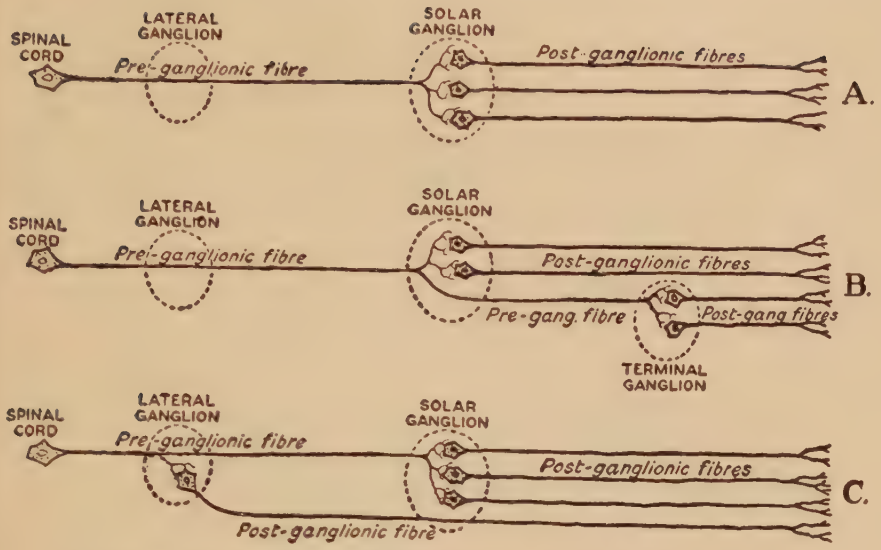
On the onward propagation of a nerve impulse

through a chain of neurons, its passage is delayed at each synapsis, hence there is additional "lost time" at each of these blocks. The relative number of the blocks furnishes a key to the differences found in reaction time for different reflexes and physical processes. This we may illustrate by two examples, one taken from the frog, the other from man.

1. If a frog's posterior root is stimulated, the time lost in the spinal cord until the gastrocnemius of the same side contracts is 0.008 sec.; until that of the opposite gastrocnemius contracts, the additional lost time is 0.004 sec.

2. In the case of the eye and ear in man the total length of the pathway to the brain is approximately the same, and so the reaction time might be expected to be equal; but this is not the case; the reaction time in response to a sudden sound is 0.150 sec., in response to a sudden flash of light 0.195 sec. The greater delay in response to a visual stimulus directly corresponds to the greater number of synapses through which it has to travel.

The valved condenser condition of nervous paths also explains another difficulty. We have seen that under certain circumstances a nervous impulse will travel in both directions along a nerve. Yet when we stimulate the motor fibers in an anterior spinal root, the only effect is a contraction of muscles; there is no effect propagated backwards in the spinal cord. No doubt a nervous impulse does travel backwards to the anterior horn cells, but it is there extinguished; it cannot jump the synapses backwards, and there is no negative variation to be detected in a galvanometer connected to the pyramidal tracts in the cord.



ARRANGEMENT OF PRE- AND POST-GANGLIONIC FIBERS IN SPLANCHNIC AND INFERIOR SPLANCHNIC NERVES.

This diagram shows the course of the splanchnic fibers, and will assist the student in grasping this method of distribution.

The great majority are arranged as in A, that is to say they have their cell stations in the solar ganglion. Comparatively few are arranged as in B, where some fibers do not reach their cell stations until they arrive at the terminal ganglion situated in the walls of the viscus (for instance, the pancreas) to which they are distributed. A few possibly and occasionally are arranged as in C, with a cell station for some of their branches in the lateral sympathetic chain.

It will be noticed that if any post-ganglionic fiber is traced backwards, there i sone and only one cell station between the central nervous system and the ultimate distribution of the nerve fibrils.

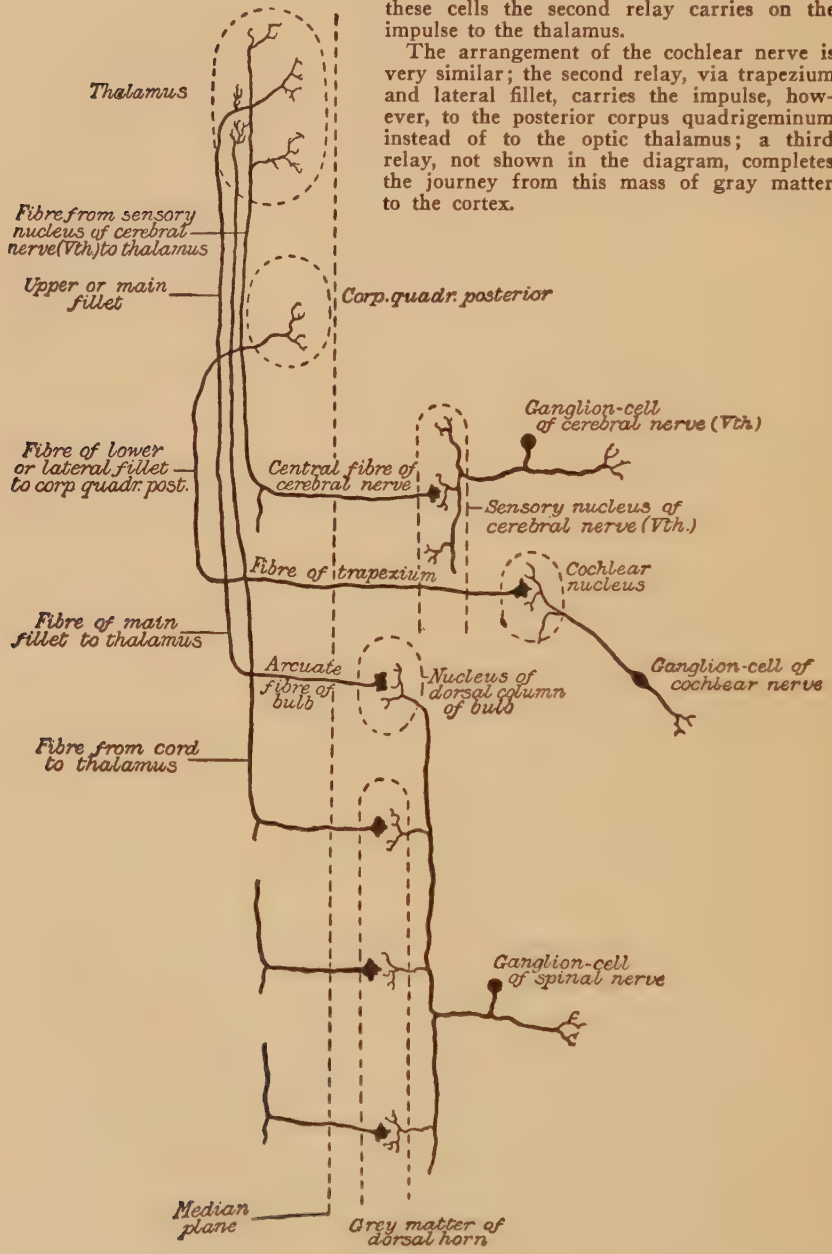
DIAGRAM OF PRINCIPAL SENSORY CHANNELS.

Beginning at the lower part of the diagram on the right hand side, we see one of the cells of a spinal ganglion. Its central axon enters the cord, runs up the posterior column, and terminates in one or other of the dorsal column nuclei (gracilis or cuneatus); the new axons arising there, called arcuate fibers, cross the middle line and ascend as fibers of the main fillet to the optic thalamus; from which as we have seen, a new relay carries on the impulse to the cortex. In the ford, however, it gives off many collaterals, some of which arborize around anterior horn cells of the same or opposite side, to form the basis of spinal reflex action. Others are shown crossing the middle line, and they ultimately reach the thalamus by the ascending tracts of the opposite side of the spinal cord and bulb.

The arrangement of the sensory cranial nerves is very similar; a cell of the Gasserian ganglion is seen sending its peripheral axon to the face region in the fifth nerve, and its central axon to arborize around the cells of the sensory

nucleus of the fifth nerve in the bulb. From these cells the second relay carries on the impulse to the thalamus.

The arrangement of the cochlear nerve is very similar; the second relay, via trapezium and lateral fillet, carries the impulse, however, to the posterior corpus quadrigeminum instead of to the optic thalamus; a third relay, not shown in the diagram, completes the journey from this mass of gray matter to the cortex.


Thalamus
Fibre from sensory nucleus of cerebral nerve (Vth) to thalamus
Upper or main fillet
Corp. quadr. posterior
Ganglion-cell of cerebral nerve (Vth)
Fibre of lower or lateral fillet to corp quadr. post.
Central fibre of cerebral nerve
Sensory nucleus of cerebral nerve (Vth.)
Fibre of trapezium
Cochlear nucleus
Fibre of main fillet to thalamus
Arcuate fibre of bulb
Nucleus of dorsal column of bulb
Ganglion-cell of cochlear nerve
Fibre from cord to thalamus
Ganglion-cell of spinal nerve
Median plane
Grey matter of dorsal horn

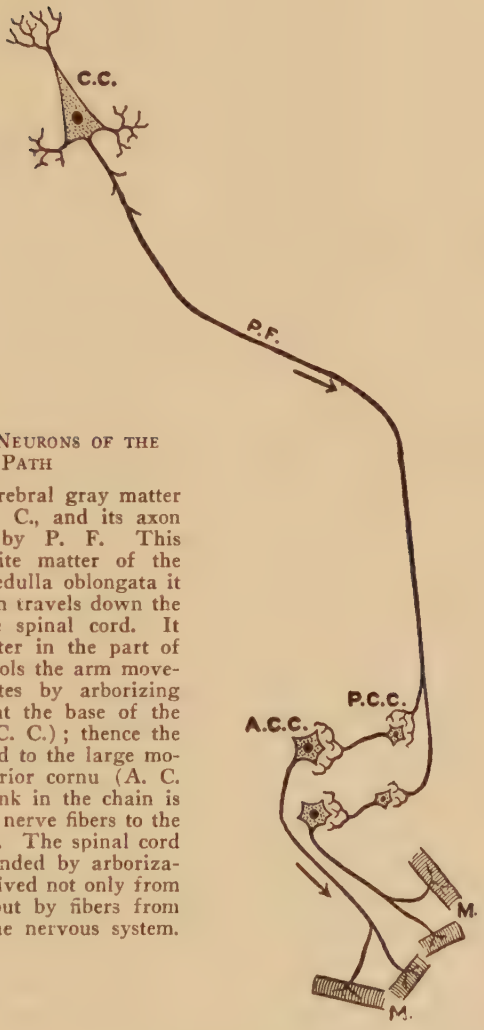


DIAGRAM OF THE NEURONS OF THE MOTOR PATH

The cell of the cerebral gray matter is represented by C. C., and its axon (pyramidal fiber) by P. F. This passes into the white matter of the brain, and in the medulla oblongata it crosses over, and then travels down the opposite side of the spinal cord. It enters the gray matter in the part of the cord which controls the arm movements, and terminates by arborizing around small cells at the base of the posterior cornu (P. C. C.); thence the impulse is transferred to the large motor cells of the anterior cornu (A. C. C.), and the final link in the chain is formed by the motor nerve fibers to the muscular fibers (M). The spinal cord cells are thus surrounded by arborizations (synapses), derived not only from the sensory nerves but by fibers from the upper part of the nervous system.

The law of axipetal conduction is no doubt true for the majority of neurons. But there is at any rate one very striking exception, namely, in the neurons of the

spinal ganglia; here the impulse passes to the body of the cell by one axon from the periphery, and away from it to the spinal cord by the other. To say, as some do, that the peripheral process is really a dendron because it conducts impulses centripetally, is simply arguing in a circle. (See chapter on The Spinal Cord as an Organ of Conduction.)

If we study synapses in the light of our present knowledge of condenser effects or even the very old fact of the action of an electrophorus or leyden jar, a physical explanation becomes at once clear and is indeed startling.

Undoubtedly synapses are constructed for their specific purpose, and are maintained by their own electro-chemical equilibrium and we know from previous disclosures that under extreme chemical or electrical conditions or even mental shock their equilibrium or function can be impaired or destroyed, as in nicotine or strychnine poisoning or anæsthetics.

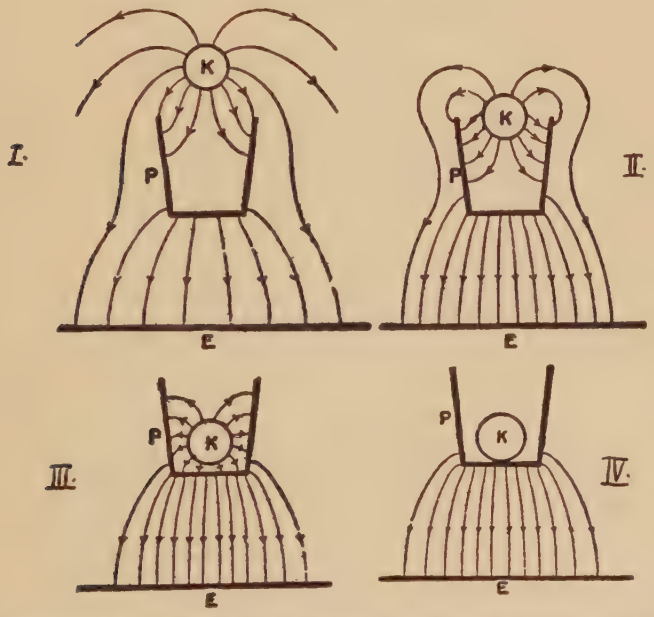
We have also shown how a nerve impulse even after transverse section does extend or distend the ends of nervous fibers so that it is even conceivable that a normal impulse or reflex impulse will alter the position or shape of these synapses, thereby enabling them to give variable condenser effects, that is according to the original nerve impulse and its subsequent change in the synapses, the synapsis itself will vary that impulse and transmit it in a different form according to the change it has assumed from the original impulse. This gives us a world of speculations and the most marvelous phenomena of body action, nutrition and decay, maintenance of body temperatures, inflammation and sclerosis, metabolism, anabolism and osmosis may at once be conceived.

It also warns us against the promiscuous therapeutic use of strong electric currents or modalities, strong drugging, or to the exclusive adaption of a theory which bases the cause of a majority of faulty body functions (disease) on mechanical obstructions or subluxations on different parts of the spinal cord.

From the foregoing and following disclosures it can be understood now how the slightest abnormal condition of any organ or part of the body is immediately manifested by an abnormal temperature.

CONDENSER EFFECT

EXPLANATION OF FARADAY'S ICE PAIL EXPERIMENT.



For simplicity the electroscope, insulating stand and silk thread have been omitted. Only the three principal conductors K, P, and the earth E, are shown. In Fig. I, the ball K is sufficiently close to P to act inductively on it; six lines are shown as falling on P, and the other six as passing to E from the lower surfaces. In Fig. II where K is just entering the pail, two lines only pass from K to E through the dielectric. The remaining ten fall on P, and ten others, starting from the distant parts of P pass to E. In Fig. III, K is so far within P that none of its lines can reach E through the dielectric; they

all fall on P and from the outside of P an equal number start and pass through the dielectric to E. It is evident that in this position K can be moved about within P, without affecting the outside distribution in the slightest, and that even when K touches P as shown in Fig. IV; and when, therefore, all lines between them disappear, the lines in the dielectric outside remain just as they are in Fig. III. K is now completely discharged, since lines no longer emanate from it, hence it can be removed by the silk cord without disturbing the electrification of P. If K be again charged and introduced into P, it will be again discharged, for the fact that P is already charged will have no effect on the final result, provided when K touches P it is well under cover.

Condenser effect in its commonly understood application in the widely used form of tuning or variable condensers on radio sets is one of the simplest illustrations of nature's workings in the physical realm of electricity, or solar electron radiation in a broader sense, wherein it manifests its constant effort to establish equilibrium of polarity according to a definite law, yet possible of attainment in millions of different ways.

FIGURE 1

Perhaps it is best explained by the saturation point discharge; a body ("A" in Figure 1 represents a condenser plate) is charged with a potential by reason of an adjacent body having an excess of electrons either in the form of a current, frequency, velocity or static charge in excess of the natural capacity of the atomic structure of this body to absorb and hold such a charge.

If A now has no direct electric connection with another body it assumes a charge in conformity with its atomic structure, conductivity, size of body, surface, or temperature, to a saturation point. According to the original pressure of the charge, it will seek again another level of a lesser potential than itself to absorb its surplus. This next level of potential we assume to be the other plate of the condenser (B). The atomic structure, conductivity, size of body, surface, temperature of B, and the distance it occupies from A as well as the conductivity of the space or medium between A and B, and the saturation point of A, are the factors which determine the exact moment of the discharge from A to B, as well as the amount and kind which B receives, and in turn can hold itself. A further duplication of the above process will result in a repetition of the same phenomena, each repetition developing its own individualities, owing to the changes (absorption, radiation, and the natural lessening of pressure of the original charge or concentration with a corresponding increase of pressure), which take place during the transaction.

The variability of a condenser can be controlled by altering the size, surface, or temperature, of A or B, increasing or lessening the distances between A and B, or changing the conductivity of the space or medium between A and B.

The working of this principle can be detected in every phenomena where an exchange of electron flow or potential occurs within a dielectric, i. e., without the

medium of a solid conductor, such as a connecting wire, or a highly ionized solution. The oscillating-, generating- or amplifying-radio-vacuum-tubes use this condenser effect. Electrolysis, batteries, electro-dynamics base their workings on it. Even with direct atom contact it is practically the same, one atom assumes a charge in complement with its capacity and transmits the excess to its neighbor. We can observe this principle and comprehend its action from the simplest form of cell life, the electron exchange from nucleus to protoplasm, to the static charge in the clouds causing a discharge (lightning), from one to the other, or to the earth.

SIMPLE EXPLANATION OF CONDENSER EFFECTS AS USED IN RADIO

A condenser is a capacity or device for temporarily holding electricity. A large condenser holds a big quantity of electrons much as a gallon jar holds water. A tiny condenser can only hold a small amount of electrons, corresponding for example to a thimble full of water.

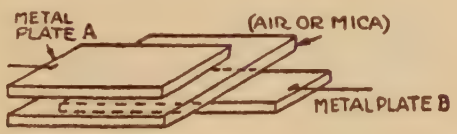
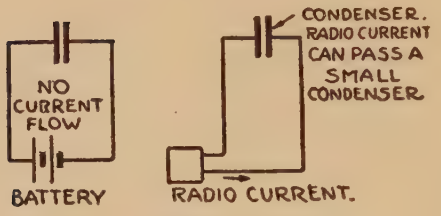


FIGURE 1

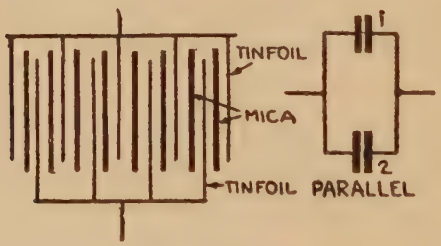
Fig. 1. illustrates how any two conducting surfaces separated by a dielectric form a condenser. The dielectric means the insulator between the metal pieces, such as air or mica. When an electrical charge is applied, a bunch of electrons rush onto the plate and set up a strain in the dielectric between the two plates. One plate is said to become negatively and the other positively charged, which means simply that there is more electricity on one plate than on the other. Both plates want to be discharged or have an equal quantity of electrons, and to do this electrons must be moved, constituting a current. Starting without unequally charged plates, if electrons are added to one plate, it is said to be charged, and the other plate has an equally opposite ability to take away this extra charge. This ability to take away the charge from the other plate is called a positive charge. The dielectric is an insulator and prevents the electron flow necessary for equalizing the charge or amount of electrons on each plate. This is then accomplished externally by connecting a suitable circuit around the condenser plates.

CHARGING A CONDENSER



FIGURES 2 AND 3

If a battery is connected to a condenser, it is charged to the same voltage as the battery can give, but no current can flow through the condenser. If alternating or radio-current is applied to a condenser, it can, however, pass right through. The condenser, charges first in one direction and then reversely, following the alternating supply current, thus acting as a temporary reservoir to take and give back electrons in large quantities. This is diagrammed in Figs. 2 and 3.



FIGURES 4 AND 5

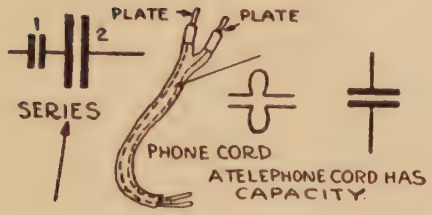
Instead of one plate for each side of a condenser there can be a group sandwiched in between insulating dielectric material, as illustrated by Fig. 4. Each group acts as one plate.

Two condensers can be connected to make one larger or one smaller condenser. The parallel connection to give a larger condenser effect is shown in Fig. 5.

PARALLEL AND SERIES CONNECTIONS

And the capacities of the two condensers simply add together. In the series connection, Fig. 6, the combined capacity is always less than the capacity of the smallest individual condenser. Thus in this example the total series capacity is less than the capacity of the smallest condenser alone.

The two wires in a telephone cord such as used in radio receiving sets form a considerable capacity, as illustrated in Fig. 7.



FIGURES 6 AND 7

So do two close parallel busbar connecting wires form a tiny radio-condenser as in Fig. 8.

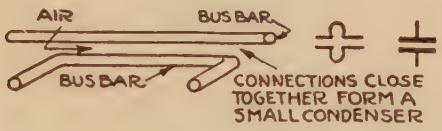


FIGURE 8

Sometimes such tiny condensers can pass considerable radio-frequency current.

Another small condenser is naturally formed in the vacuum tube used in a receiving set, as illustrated in Fig. 9.

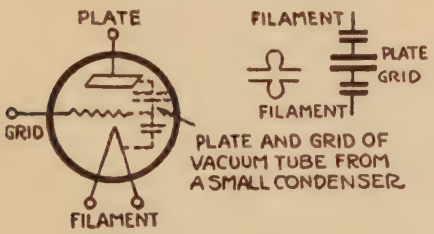


FIGURE 9

TYPES OF CONDENSERS

The main types of condensers used in radio sets are, firstly those using an air dielectric and usually variable or adjustable as to capacity size, and, secondly, those using mica or some other solid dielectric material. The latter are more compact and can be fixed or adjustable. Air is the unit in measurement of dielectric capacity, and other insulators, as mica, have a much larger dielectric constant. Thus for the same dimensions mica can hold a greater dielectric strain and form a larger capacity condenser than air. Some materials, as paper, are not good dielectric because they absorb and dissipate

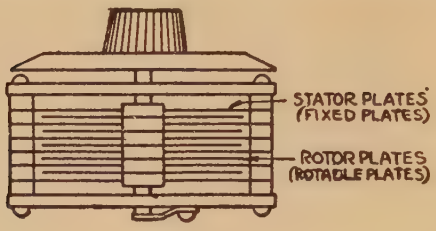


FIGURE 10

energy. Figure 10 diagrams the popular type of plate variable condenser and Figure 11 shows one of the smaller types.

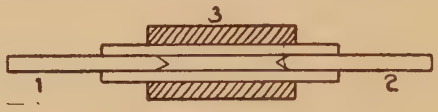


FIGURE 11

The windings of an ordinary audio-frequency transformer have considerable capacity of condensers in and between the windings, as illustrated in Figure 12.

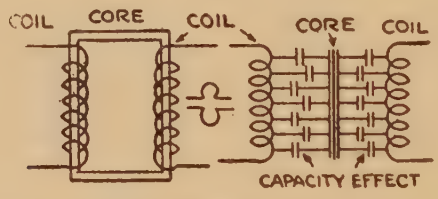
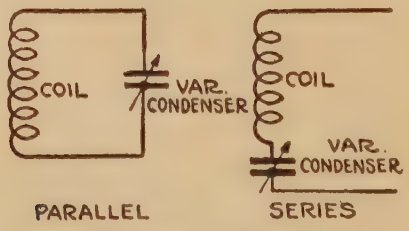


FIGURE 12

COMBINATIONS OF CONDENSERS AND COILS

Figures 13 and 14 show the two principal connections of a condenser and a coil as used in tuning. Such combinations become adjustable pack-



FIGURES 13 AND 14

ages to fit certain frequencies. A vernier condenser, Figure 15, is really two, one large and one tiny, so that the size of the frequency container of the condenser and coil combination may be more finely adjusted.

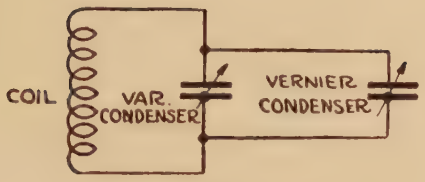


FIGURE 15

Body capacity occurs when a small condenser is formed by the operator's hand or body and the receiving set. The human body when insulated from the earth makes a small condenser, Number 1 Figure 16, with it. The

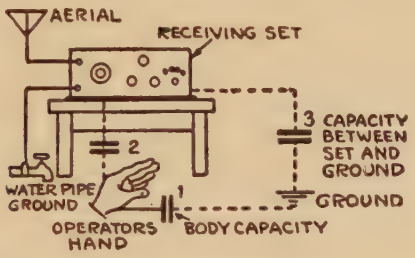


FIGURE 16

hand insulated from the receiving set makes a tiny condenser, Number 2, with it. The set and its batteries will usually make a condenser, Number 3, with the ground. This has an interfering effect in tuning some sets and can be avoided by grounding the movable plates of the condenser used in tuning the set or by employing a capacity shield.

ELECTRO-STATIC FIELD

There is an electro-static field set up between the plates of a condenser, as diagrammed in Figure 17. Tubes of force extend in the dielectric between

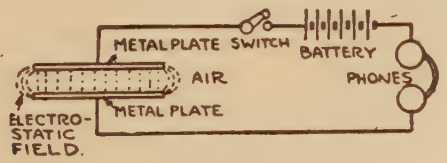


FIGURE 17

the plates. In an aerial, such tubes of force extend between the aerial wire and ground, as indicated in Figure 18. A transmitting aerial sends off a pair of field components, one electro-magnetic and the other electro-static and at right angles thereto.

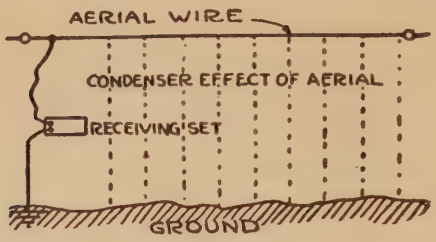


FIGURE 18

Condenser Effect: The real explanation of gas conduction was not found until after the discovery of X-rays in 1895. The convincing experiments were made by J. J. Thomson, or at his instigation in the Cavendish Laboratory at Cambridge, England. The new work grew obviously and simply out of the fact that X-rays, and a year or two later radium rays, were found to discharge an electroscope, i. e., to produce conductivity in a gas. Theretofore no agencies had been known by which the electrical conductivity of a gas could be controlled at will. Thomson and his pupils found that the conductivity induced in gases by X-rays disappeared when the gas was sucked through glass wool. It was also found to be reduced when the air was drawn through narrow metal tubes. *Furthermore, it was removed entirely by passing the stream of conducting gas between plates which were maintained at a sufficiently large potential difference.*

When it was found, further, that the electric current obtained from air existing between two plates and traversed by X-rays, rose to a maximum as the potential difference between the plates increased, and then reached a value which was thereafter independent of this potential difference; and, further, that this conductivity of the air died out slowly through a period of several seconds when the X-rays no longer acted, it was

evident that the qualitative proof was complete and that gas conduction must be due to charged particles produced in the air at a definite rate by a constant source of X-rays, and that these charged particles, evidently of both plus and minus signs, disappear by recombination when the rays are removed. The maximum or saturation currents which could be obtained when a given source was ionizing the air between two plates whose potential difference could be varied was obviously due to the fact that when the electric field between the plates became strong enough to sweep all the ions to the plates as fast as they were formed, none of them being lost by diffusion or recombination, the current obtained could, of course, not be increased by further increase in the field strength.

CHAPTER XII

THE PSYCHICAL PROCESS

THERE is a degree of obscurity existing in pathology, how do mental operations normally take place in the various regions and structural elements of the brain. In the functions of other organs, such as the heart, liver, or kidneys, the relation between structure and function are fairly well known, and are simple in comparison with those of the brain. The biological significance of the brain does not permit such explanation. The brain distinguishes, beholds, hears, smells, tastes, touches, examines, excites, innervates, inhibits, speaks, writes, remembers, thinks, imagines, reasons, it wills, it hesitates, it suffers, and it rejoices; to sum it up, we can say that it is at once an observatory, an archive, a tribunal, a government, and a number of other things for which we do not even have the conception to give them a name. Between this marvelous complexity of its functions, and the deceptive homogeneity of its structure, there is a gap that is indeed difficult to bridge.

Corroborating proof of an indisputable nature obtained by Broca and Marcus Dax in 1862, demonstrated conclusively that the seat of function so undisputable psychic as that of speech is located within a fairly restricted but anatomically not so definitely defined area of the cerebral cortex, and that it is limited to one side. This seems to justify the conclusion that other mental functions are similarly localized in distinct areas of the cortex of the brain. A few years later experimental localization made by Fritsch and Hitzig (1874) resulted in the discovery of the motor zones and the local-

ization of the visual centers in the occipital cortex. Two questions that are still not exactly answered in Physiology are: Do we think by the reproduction of direct images, or by means of symbols that are formed elsewhere, and how are these various symbols distributed over the cortex? Are they unilateral as in the case of speech, or bilateral like the ordinary sensations? Flechsig and Ramon Y. Cajal have opened the discussion as to the existence of Psychical centers, and have examined the problem with great care, and it is mostly due to their extensive work that we owe our present knowledge on this subject.

Experimental physiology has localized the so-called motor and sensory centers in various cortical zones, but there are portions that remain unexplored and there are other regions which though explored, are still subject to dispute owing to the fact that the information given by the various observers has not been unanimous. Consequently if we tried to construct a chart of the cerebral cortex, and to establish the exact line of division between the spheres of sensation, motion, and psychical activity two great questions would remain still unanswered: Is any portion concerned exclusively with psychical activity? And, what extent of the cortex is concerned therewith? With regard to a third question: Are there specific centers for the various forms of psychical activity, and if so, what are they, and what is their location? The solution seems to be beyond the powers of experimental physiology.

Answers to these questions have varied, according to the changes that have taken place in the doctrine of localization, which from 1870 until the present time have been considerable. To the earliest workers the cerebral cortex appeared to be a mosaic of sharply

defined centers. This view is known as the *theory of juxtaposition.* According to more recent observers, each of these centers shades off into a marginal zone, in which the functional activity is less marked, and with which the neighboring centers also blend. According to these observers, the cortex is a collection of areas or centers, with intersecting or superimposed margins. This is the *denticulation* theory (Luciani, Exner). Other physiologists, such as Wundt, and Munk, while not denying the existence of denticulations, maintain that the cortical centers have an arrangement corresponding to that of the organs and peripheral areas which they innervate, and that in these centers the groups of sensory cells are mingled with groups of motor cells. This is the theory of *promiscuity.* It is not opposed to the denticulation theory. For example, if the occipital lobe contains the center of vision, in it should also be found the motor centers for the eyes; if the Rolandic zone initiates the voluntary movements of the limbs, here also should be contained the center of their tactile and muscular senses.

There are a number of other theories all so far unsuccessful in their exact localizing of specific psychic functions in a specific area of the brain.

Investigations made by Flechsig and Maynert about 1884, showed clearly that the sensory functions in the embryo develops, and is organized before those of motion. The process of myelination which coincides with the functional maturity of the paths of conduction, occurs at different times in its separate tracts. It begins in the cerebral hemisphere in the fifth month of foetal life, continues during the first year after birth, and follows a very definite chronology, both with regard to the order in which the various tracts are myelinated

and the precise time at which each reaches maturity. The first to become myelinated are the fibers of the olfactory tract, lemniscus, and optic and auditory tracts (the cortico-sensory fasciculi) which run in ascending direction, and are projected in the sensory centers; next, at various intervals, the pyramidal fibers, or cortico-motor fasciculi, which run in a descending direction, projecting themselves from the motor centers; and, lastly, the fibers which we shall call cotico-cortical, which, as they appear neither to leave the brain nor to enter it from without, are considered to form a separate system, distinct from that of projection, being neither ascending nor descending.

These fibers, which both arise and terminate in the brain, are much more numerous than the others. They constitute the system of associations. To this system of association there belong (1) all the fibers that pass from a center of projection to associative centers; (2) all of those that pass from associative centers to centers of projection; and (3) all those that pass from one associative center to another. They have this feature in common—that they connect centers with centers, cortex with cortex.

The topographical delineation of the sensory and motor centers is as follows: (1) The Hippocampal convolution and adjacent parts, or olfactory region; (2), the posterior part of the first temporal convolution and its neighborhood, or the auditory region; (3) the cuneus and its neighborhood, or the visual region; (4) the central convolutions (ascending frontal and ascending parietal), the paracentral convolution, the posterior ends of the first and second frontal, or the somaesthetic region, which is the seat of sensory and motor activity as far as the limbs and trunk are concerned.

All the rest—that is to say, about two-thirds of the cortex—is the psychical region. It is divided thus:

1. Prefrontal zone.
2. Insular zone.
3. Parieto-occipito-temporal zone.

The centers of speech are included in the psychical zone, because they are late in becoming myelinated. Their functions are of a purely psychical character.

Despite a great deal of criticism this work of Flechsig's has not been disproven as yet. No doubt future investigations will increase these centers considerably. Flechsig, however, does not pretend to distribute among these centers the various functions of intellect as they are classified by introspective psychology, or to designate the subjective aspects of the mental process that takes place at any single spot in the brain. He merely says: "Here there is developed a function which is embryologically late—presumably it is psychical." And adds, if the locality in question communicates with, for example, the special center for vision, for verbal articulation, or for manual movement, it is probable that its function is that of controlling the mental images, or corresponding impulses, and elaborating the products of the subordinate center. He is only specific in one instance, and that is in regard to memory. From it there can be deduced the general law that for every specific center of sensation, there is a neighboring or communicating zone of the cortex, a corresponding memonic repository. It can hardly be rash to localize the memory of images or rather of their psychical elaborations, in a cortical zone which possesses the embryological and anatomical requirements to which reference has been made.

In the investigation of mental localizations from human pathology we obtain most valuable data. It appears that one part of the cortex sees objects and that a different part recognizes them after they have been seen. Psychology has already perceived the importance of distinguishing between acts of pure sensation and the mental acts of symbolic representation. Clinical observation has absolutely confirmed this distinction of separating two entirely symptomatic pictures, mental blindness and cortical blindness (the loss of vision) and pathological anatomy has confirmed these observations by showing that the two functions are located in different cortical centers.

The centers for speech (spoken, heard, written, and read) not only constitute a solid foundation for psychical localization, but at the same time reveal a fact of the highest importance that cerebral physiology had never suspected. These centers which are eminently psychical, are situated in contra-distinction to the motor and sensory centers, in the left hemisphere, except in cases of left handedness, and are not represented at all in the right hemisphere. Thus, at the first revelation of the psychical centers, there comes to light the law of unilaterality. The psychical functions, arising gradually, become unilaterally developed in special centers, which go to augment the cerebral volume. This unilateral development is an adaptation, the utility of which is evident, and therefore also its cause. The peripheral organs of sensation and movement are double, the human body being divided into two lateral and perfectly symmetrical halves. Hence, the duplication of their centers, whereby man is enabled to observe with accuracy the place and course of external events, as well as the objective and direction of his reactive move-

ments. On the other hand, symbolic or abstract representations not having a precise position in the environment, have no need of topographical collation in the body, and therefore they are not separated into right and left.

Hence, the psychical centers, like their functions emancipate themselves from the law of symmetry which regulates sensibility and movement. This adaptation has the advantage of anatomical economy, because it saves the psychical functions from a cumbersome duplication of organs in the two cerebral hemispheres. In consequence of this economy more psychical centers can become specialized in a given area of the brain, provided it is granted that they are in process of being formed also in the right hemisphere, as is now believed not without good reason.

With the advance of microscopical analysis and new methods of investigation we have now a great volume of facts for most of which science is especially indebted to Ramon Y. Cajal, so that now anatomy distinctly supports the view of the plurality of psychical centers. Where the distinction between center and center is not due to a peculiarity of internal structure, it arises from a special nature of their external relations. While the psychical regions taken as a whole present an individuality of structure which enables us to distinguish them from the zones of projection, we do not as yet know of any histological characteristic by which to distinguish the various psychical centers from each other. The presumption of their specific functional nature has therefore, no other basis than that of the individuality of position. In other words, anatomy indicates in a general way, the existence of suprasensory and supramotor centers, the subdivision of which corresponds to that of

sensations and movements, but does not seem to admit more exact specification.

A cerebral histology shows that the sensory paths, while narrow at the periphery and in the first part of their course, are broad at their termination in the cortical centers, because the nervous wave, as it projects itself into the cortex, affects therein a much wider area than that from which it started. This can be seen for example in the case of the optic tracts. A rod of retina stimulated by a microscopically minute ray of light transmits the excitation through various tiers of neurons, the number of which increases rapidly and steadily in its course from the periphery to the center, thus the nervous current, like an avalanche, invades a kind of imaginary cone, the apex of which is in a rod of the retina, and the base of which corresponds to the cortical projection. In the supposed example the retinal stimulation is of imaginary minuteness, certainly less than that required for the slightest sensation that is perceptible. Its complexity in the case of an ordinary sensation may be conjectured. An immense number of cortical cells are really concerned in the reception of a visual image. The cortical projection of a retinal image, however small this may be is in fact the sum of many partial projections, and exactly corresponds to the number of rods excited. As however, the retinal elements are very close together, the projections corresponding to each of them in the visual cortex are partially superimposed at their termination like the circles that broaden out on the smooth surface of water under the action of rain. Every drop forms its own circle on the water and every circle blends in large part with its neighbors without having a single point that

does not communicate with the other circles (excepting the outermost circles).

At the same time every circle has its precise and mathematical individuality, and one could not take the place of another.

SCHEME OF THE OLFACTORY BULB

1, Stratum of the olfactory fibers; 2, stratum of the glomeruli; 3, external plexiform zone; 4, line of mitral cells; 5, internal plexiform zone; 6, stratum of the granules and central fibers. a, Olfactory fiber; b, glomeruli; c, cell of association between the glomeruli or external granule of Kolliker; d, mitral cell; d', primordial dendrite of mitral cell; d'', accessory dendrites; d''', retrograde collateral; e, pinnate cell; e', axis-cylinder of pinnate cell;

f, cell of Golgi; g, cell of Blanes; h, cell of Cajal; i, granule; k, centrifugal fiber coming from the centers; l, centrifugal fiber coming from the bulb of the opposite side (from a pinnate cell) by way of the anterior commissure.

A still more marvelous example of the way in which the functional excitations as they traverse the paths of centripetal projection spread themselves out, though in a definite manner, and perhaps also with a certain pre-established rhythm, is that which is supplied by a careful histological examination of the olfactory organ. The odorous stimulus which has been received by a peripheral element of the Schneiderian mucosa (not represented in the figure) meets, even at its first station in the olfactory bulb, a series of different elements which hand it on to the cortical center, or return a part of it to stations already passed, or send it off laterally to other intermediate elements, thus interrupting its progress at every step, as if to widen and prolong its effects.

Every olfactory cell of the nasal mucosa send to the bulb a fiber a, which terminates by ramifying in the glomerulus b. In the glomerulus and around it there are the external granules of Kolliker, c, which by means of their dendrites, receive stimuli from the glomerular fibers with which they are intermingled, and transmit them to two or more contiguous glomeruli by means of an axis which has a horizontal course. To every glomerulus two other varieties of cells also carry stimuli, namely, the large mitral cells and the small pinnate cells.

The mitral cells, d, dip into the glomerulus by means of a large dendrite, d′, the primordial dendrite, so called because phylogenetically it is the oldest, This process represents the direct organ of olfactory transmission, while other dendrites; d″, of the same mitral cells, run horizontally for a considerable distance in the external plexiform zone, where they receive various kinds of indirect stimuli, which we shall enumerate presently. The axon of the mitral cells forms the true olfactory highroad; but, before entering the external root of the bulb, it sends out several recurrent collaterals, d′ ″, which carry indirect stimuli to the accessory dendrites of innumerable mitral cells. There are, therefore, precortical associations which determine dynamic exchanges between the mitral cells, as also between the olfactory glomeruli, and all these physiological processes occur in a region which is not yet the seat of consciousness.

The pinnate cells, e, possess primary and accessory dendrites analogous to those of the mitral cells; but the destination of their axons is not cortical. The axon crosses the internal plexiform zone which lies just above the mitral cells, sends off numerous collaterals which cannot be traced farther, and then passes toward the centers, but crosses by the anterior commissure to the olfactory bulb of the opposite side. There it distributes collaterals throughout the internal plexiform zone, and terminates by forming arborizations around the bodies of the mitral cells. Consequently, these axons, which are more delicate than the others, are seen in each olfactory bulb under two different aspects; some are leaving, e, while others are entering, 1. These likewise come from pinnate cells—that is to say, from those in the bulb of the opposite side.

This does not, however, exhaust the fact regarding the diffusion of the olfactory stimuli. In the internal plexiform zone there are three types of cells with short branching axons. Some—the cells of Golgi, f—are provided with a small axon, which ramifies for a short distance in the plexiform layer itself. Others, of larger size—the cells of Blanes, g—possess an axon which similarly ramifies for a short distance, but somewhat more widely, within the zone in which it arises. Lastly, still others—the cells of Cajal, h—send their axons into the external plexiform zone, in which they ramify and convey supplementary stimuli to the accessory dendrites of the mitral cells. These three types of cells receive the nervous wave from the collaterals which ramify in the zone in which they lie—that is to say, the excess and derivatives of the principal current—carrying it back to the mitral cells.

Even this is not all. The internal zone, which contains the bundles of centripetal and centrifugal fibers, 6, is densely packed with certain curious cell elements—the granules, i,—which, like the amacrine cells of the retina, are devoid of a true differentiated axon. They have a small tuft of central dendrites and a long thick peripheral prolongation, which passes perpendicularly through the internal plexiform zone and the row of mitral cells, and ramifies in the external plexiform zone in the form of a plume of fine spinous dendrites. It is probable that these amacrine cells receive stimuli upon their bodies and central dendrites from certain fibers which run in a centrifugal direction from the olfactory cortex, k; that in traversing the internal plexiform zone they receive other stimuli on their trunk from the innumerable collaterals which occur in this position; and that all of these stimuli are discharged upon the accessory dendrites of the mitral cells by means of the terminal ramification.

We leave out of account all the deviations, the windings, and the progressive arborizations that are concerned with even the most insignificant of the olfactory stimuli in the labyrinth of the cerebral cortex. It is sufficient to have demonstrated that from a single cell of the Schneiderian mucosa there can be developed a nervous current capable of undergoing enormous diffusion, and that, before it has left the olfactory bulb, it has already been subjected to diffusions and transformations of the greatest significance. It is probable that, arising in this position from many peripheral cells, the physiological stimulus, whatever its strength and nature, ends by invading the whole of the olfactory cortex. Thus the olfactory avalanche may be imagined as a cone which, having its apex in a peripheral cell, extends its base over the whole olfactory region of the cortex.

From this, it follows that, while a single olfactory sensation is collectively the work of innumerable, perhaps of all the cells of the olfactory cortex, stimulated thereto by the unconscious, but, nevertheless, highly complicated, activity of precortical cells, every cell of the olfactory cortex must take part in the sensation of every possible odorous stimulus, making different responses to each stimulus which is recognized as distinct.

From the foregoing arise certain principles of extraordinary importance. The elementary sensory process of perception for example, of an isolated stimulus affecting a single retinal rod, if that were possible, are always pluri cellular phenomena. Even more so a psychical process. In fact, the combined activity of many neurons is a necessary condition of consciousness and the isolated activity of a single cell, (or of a few) constitutes only the fragment of a conscious phenomena. Therefore, a single cortical element is not by itself capable of producing a concrete image, not even that of a luminous point that has impinged upon a single rod or cone of the retina. Our present knowledge of electron activity gives ample proof of this fact. Since now actually every cell of the visual projection corresponds

to many rods and cones of the retina there are produced fragments of sensations or symbolic images, which, blending with innumerable functional contributions from other central cells, give rise to the psychical art in its infinite varieties, that is to say, to sensations and images that are capable, more or less, of asserting themselves as conscious facts.

Every cortical cell is both an organ of reception and an organ of discharge, inasmuch as it can pass on to other cells the stimulus it has received. If, as an organ of reception, the cortical element is able to receive various stimuli, and not merely one, it has the advantage or a certain versatility also as an organ of distribution for, when once impressed passively it can place itself in function in co-operation now with one, now with another of the near or distant cellular groups with which it is connected anatomically. These anatomical relations represent as many functional possibilities, which are realized or not, according to the circumstance of the moment. The course of thought is, therefore, very precarious. Its variations depend not only upon external events, but also upon the intimate changes in innumerable cells which form part of the system accessible to a given nervous current and which are each independently able to attract or to repel this current. Theoretically, and according to all known laws of electron transmission, absorption and radiation the psychical process should be able to reach any point with which there is an anatomical continuity, and so work uniformly according to these laws which are in constant evidence and recurrent in every other physical phenomena.

Practically, and in fact, it encounters resistances and attractions sometimes of a transitory nature which do not allow it either to go beyond, or to stop short of a

given course. On account of this "dynamic variability" the nervous currents can assume an almost infinite number of material figures or vibrations in the cortical space and of subjective figures or vibrations in consequence. In the "polydynamism" of the cortical cells must be sought the principal cause of the variety of directions, velocities, or vibrations that the nervous currents of the brain are able to take. We cannot possibly ascribe this "polydynamism" or power of variability of impressions to the actions of synapsis, though they are present in the brain as in the nerve circuits of the whole organism. The synapses act according to certain laws and the variations of their actions, could be foretold or estimated when the nature of the impulse and the conditions surrounding the synapses are known. (See chapter on Synapses.)

The purely physical conception has in this case no value because in spite of the anatomical invariability of the cerebral fabric we have the very great facility with which the dynamic processes of the brain can vary. Since we have seen the psychical reaction, however simple it may appear, always concerns many nerve cells, and since each of these cells can only have a fractional share in the functional act it will suffice that a single cell of the cynergic system or of the "isodynamic pleiades," alters, increases or suspends its active cooperation in order that there may be a minute and most delicate modification of the complex of the psychical reaction. The difference, however small it may be, of a single thought will not be without effect on the development of successive images, ideas and emotions.

There is no doubt that the investigation of mental localizations, by experimental cerebral physiology, by

the anatomy of atrophies, experimental degeneration, the chronology of myelogenesis, the pathology of focal lesions, and the normal histology of the brain has passed beyond that of academic discussion. And it is now generally acknowledged that the mental functions are contemplated in different zones from those of sensation and motion, so that it remains only to be discovered now if psychical activity is not further subdivided in specific centers with distinct functions. So far we know that psychical centers are the depositories of representations. Divided into groups corresponding to those of the sensations, and composed of their accumulated residua, the representations supply material to the memory, the imagination and logical thought and constitute a higher element of intellectual activity. The sensory and motor centers are concerned only with immediate and fresh reactions of which they are unable to preserve any trace. The permanent, if incomplete records of the events that concern the centers of projection are preserved in other centers; and from this position under certain physiological conditions, they give rise, when need be, to a facsimile of the original occurrence, or to the reproduction of a single detail which, assumed in consciousness as a symbol, suffices to represent the whole complex. The passage of the recallable records from the double centers of sensation to the single center of representation, takes place along fibers of the same and of the opposite side, which run from the two hemispheres of the brain and converge separately to one or the other of the hemispheres. The representations, for the very reason that they mark the progress of intelligence, from a purely projective to an associative phase of consciousness, which requires organs of its own, are the necessary and sufficient factors to secure that development,

to which the brain can attain, beyond the sphere of the sensory and motor functions in adult human beings, and in virtue of which it immensely surpasses the most fully developed brains of the new-born, as well as those of adult lower mammals, not excluding the apes. The unilaterality of the representative centers has been recognized by several neurologists as far as regards facial expression and the performance of instrumental music. It appears that mental blindness is more profound and involves a greater number of visual images when the lesion is upon the left side. Some interesting facts in point are: In blindness acquired from a cortical lesion, visual records are not lost, as is well known though the power of recalling visual images remains unaffected; it is, therefore, more than theory that this power is localized in an area of the cortex distinct and apart from that concerned with visual sensation.

When a certain area of the occipital cortex is destroyed there is hemianopsia, of halving of the optic images, but not halving of the representation. The mechanism that gives rise to the representations must therefore differ, not only topographically, but also intrinsically from that concerned with sensations.

Ramon Y. Cajal very clearly puts it this way: "Representation is an incomplete, indistinct and variable synthesis of similar images which are introduced into and mingled in the brain at various times. It has no assignable position among external objects. It can be renewed as the result of internal stimuli. On the other hand, sensation is an immediate and exact, but ephemeral and not renewable impression of a given external phenomenon."

The assumption that things are perceived in one place

and thought of in another, also makes very clear the pathogenesis of hallucinations.

In order to conceive this more clearly it must not be assumed that ideas are stored accumulatively and are issued one by one from the cell in which they are enclosed, as though they were matter, but this process is rather one of simple localization of impressions which, in order to pass to the actual state and become ideas, require a dynamic effort of synthesis. This synthesis is under the control of physiological changes and it is effected not within the limits of a single cell, but over great distances, and is concerned with a multitude of more or less independent cells, which are capable of being employed in various ways according to circumstances and of associating themselves in synergic activity, even though they belong to different centers. In short, the psychical centers do not contain ideas but the ingredients of ideas; or better still, they have the capacity of producting the ingredients that serve to compose the ideas or to symbolize them.

The sensorial centers of vision are a looking-glass, those of hearing a resonator, those of cutaneous sensibility an instrument for instantaneous signaling, and nothing more. The mnemonic representations of external phenomena and of our own bodies are built up in other centers in the form of symbols. These are direct symbols. From the center of representation the direct symbols can pass to higher centers, in order to form more general and more abstract conceptions; these are symbols of symbols. The law that the functional processes are always pluricellular also holds, however, for these centers, as does also the law that every cell has the power of resisting or yielding to stimuli, and of reacting in various though similar ways. Further, the

activity of a single cell never corresponds to an imaginable figure, whether it be of the most elementary or of the most vaguely symbolical nature, unless it is compounded with that of very many other cells, perhaps thousands, scattered here and there in the brain. For this reason, the precise contents of the psychical treasure-house, as also the degree of intellectual capacity, will always be an enigma to the anatomist. Only the generic type of the intelligence, the enumeration of the functions that belong to the various cortical centers, and the feebleness or the extraordinary development of a psychical function, are problems capable of solution by anatomy, and of being made the subject of future corollaries through the clinical study of mental diseases. In this direction an anatomist, G. Retzius, has been able, without laying himself open to the charge of having adopted phrenology, to describe the brains of mathematicians possessing very great power of abstraction, and to perceive its equivalent in the anatomical structure. In like manner, it would be legitimate and fitting to study the brains of orators and musicians endowed in an eminent degree with the very special natural gifts which are essential for the exercise of eloquence and of the faculty of musical composition; and if from individual psychology we pass to psychiatry, it may perhaps one day be possible to find in the brains of idiots and of partial dements the explanation of their anomalies and deficiencies, both as regards to quantity and quality. On that day the outlines of a vast scheme of psychopathological anatomy will begin to be discernible, and psychiatry will have crossed the narrow strait which separates it from the other departments of clinical science.

It excites a certain misgiving in me when I notice

the popular applause and attention new scientific inventions or accomplishments, great as they are, arouse when I contemplate the uncanny, marvelous chain of events involved in phenomena which are as a whole considered quite commonplace. It is not only the ability of the psychic brain process to conceive, and plan, accumulate and remember impressions, but also the ability of the psychic process or intelligence to utilize matter, the atom and the electron to formulate and construct a material medium *which in itself* is *inert and meaningless,* until another psychic process or intelligence, through the physical nervous system and its psychic center conceives it again and experiences the same emotions or knowledge than the originator. When I reflect on these miraculous facts, it inspires me to unexpressable exaltation and I beg the reader's indulgence for this dissertation, which commonly is not classified as exact science, having made the promise not to philosophize or speculate, though strictly adhering to the original resolution, *it is science,* for they are facts of nature as we know them. As examples of such translations from psychic impressions to inert physical matter and back into psychic, I cannot imagine anything more sublime than the deaf Beethoven, tortured by the tragedy of his affliction, wandering hours and days over country roads, through rain, storms and sunshine, absorbing mentally the elements at work, colors, animal and human life in action, contemplating this spectacle, he feels great emotions, which his particular genius *hears, mentally,* as an immense musical symphony. His "Will" now compels his nerve impulse into action, electro-chemical changes, actuate his motor nerves and, he plays it. He cannot hear it, but he writes it down on paper, each note, each tone, a specific dot or mark, an

harmonious composition for a full orchestra, and there it is on paper, inert matter, meaningless as such except so much paper and ink; destructible as such, subject to electro-chemical changes, which, while altering its atomic integration, would not destroy one atom, but loose its hidden meaning entirely. Yet, these physical dots and lines may be copied and reproduced by a process which involves only the purely physical action of sight, i. e., the reflection of light velocities, electron flow, from white and black music to the retina, thence through nerves to the cortex and a mental translation which actuates the motor nerves to reconstruct or produce these impressions, without ever knowing the real meaning of the composition.

And here, though we accept it as commonplace, the mystery is, this reproduction still has, or has again, the same original meaning. As long as the material paper and ink remains intact, time cannot affect the meaning. So that generations later intellects, with specific training and development can, by seeing dots and marks and playing on instruments (a physical and mental process), set an electron flow in motion, which, as harmonious sound waves strike our receptor nerves, and reproduce in thousands of human beings at widely separated places, and different times, emotions and impressions felt and conceived by the psychic center of the lone, deaf Beethoven years ago.

It sets my imagination spinning when I reflect on the religious fanaticism of Saints, who joyously endured a torturous death for the gratification of their Deity, whether that was a God, Buddha, Allah, Zeus or whatnot, and whose physical relics can, hundreds of years later, inspire in thousands of diseased and crippled human beings, emotions strong enough to overcome and

actually free them from their physical afflictions. And it puzzles me beyond description when I consider the spectacle of the blind Pulitzer, starting as a penniless immigrant boy, directing the actions and thoughts of thousands, through the medium of his great newspaper, and then the poor wretch, who had the advantage of learning and wealth, ending his career in the gutter, an outcast sot.

Science seems to have a reasonable understanding of matter, physical laws and things that work identically under the same conditions but who can fathom the phenomenon or law, that ultra or super condition of which we know not the beginning nor the end; which seems to be always and everywhere, but which seems somehow to fuse with the physical and of which the psychic centers of the cortex of the brain, must be part of. Where matter appears dissociated from this phenomenon, we can determine with fairly exact accurateness, just what is going to take place under given conditions. But where it is associated with matter, we are stumped by the dominating and determining influence it has over matter. Hence even the most exact knowledge and complete control of all physical functions would still be insufficient for man to master biology, or to evolve a therapeutics, which would respond accurately to physical ministrations.

At this juncture, we must express our admiration and gratitude to those workers, past and contemporary, whose marvelous and unbelievable painstaking experiments and investigations, have made it possible for this writer to present to the reader, such coherent glimpses of the most wonderful, intricate, yet uniformly operating physical functions, as it is hoped this book may represent.

It has been our intention, and great effort has been made to have the names of all scientists whose works have been material in the development of this treatise, mentioned and quoted in the particular discussion which falls under the scope of their work.

CHAPTER XIII

SUMMARY

IN experiments to determine the origin and effect of nerve impulses, of nerve conductivity, the effect of trauma, and other factors on the brain, its resulting cell-injuries and changes, and the resulting rise and fall of blood pressure, respiration and temperature, nerve exhaustion and restoration, we are indebted for a great deal of data and information to Dr. George W. Crile. While the conclusions which he draws from his extensive studies are not entirely in harmony with the whole facts (this is just another example of how the findings of practical experiments very often lead to wrong conclusions), especially in regard to his theory that the brain is the GENERATOR OF ELECTRIC ENERGY FOR THE BODY, his work is nevertheless of the greatest scientific importance.

These definite conclusions can be drawn, i. e., that the degree of shock and resulting functional changes are proportional to the intensity and number of injuries multiplied by the excitability of the injured tissue: In other words, the greater the number and importance of nerves affected in such trauma, the greater the physiological changes; for instance, injury of the skin of the paws of an animal, causes much greater circulatory and respiratory changes than similar injuries to the skin of regions with a lesser supply of surface nerves. Again, the physiological disturbance is decidedly less when nerves are severed quickly with a sharp knife, than when they are dragged or torn slowly. Electric or thermal irritations of nerves cause blood pressure

changes very similar to those caused by mechanical irritations.

The gradual destruction or even piece-meal removal of the hemispheres seem to cause no changes in blood pressure and respiration, provided no pressure or trauma is exerted on the base of the brain. Injury of the medulla causes a momentary rise of the blood pressure followed by immediate fall to zero.

Nerve trunks may be physiologically blocked by local anaesthesia so that neither afferent or efferent impulses of any kind can pass. Injuries or extreme excitations of parts or areas having important nerve connections result in physiological changes of the brain cells in the cerebellum, the cortex, the medulla and cord; significant is the fact that brain cells show no change when such injuries or excitations are limited to areas which are disconnected from the brain by severing the spinal cord, or by local anaesthesia (blocking). In these experiments it was also definitely proven that it is the blocking of the afferent path from the seat of injury which prevents the changing of brain cells.

In experiments conducted by inducing artificial anaemia to determine the resulting effects, it was found that restoration of function returned in the following order: Respiratory plexus, vaso-motor, corneal reflex, cutaneous reflex; in all such cases there was a marked period of loss of intelligence, lack of psychic response to stimuli, inability to recognize food and drink, response to stimulation was purely reflex, or wholly absent if memory was involved. The observations showed that the cortex suffered the most, and was the last to recover, and after recovery, a marked degeneration of a number of the fibers in the pyramidal fasciculi, which were traced from the cord to the cortex, or a permanent

loss of many nerve cells in this region, had taken place.

Extensive research work done by Crile, Austin, and Hitchings for the determination of functional changes caused by the effects of prolonged loss of sleep and restoration by sleep, showed the following: In a period of 100 hours during which sleep was not allowed, exhaustion developed gradually until death. No known stimulative agent could prevent the inevitable exhaustion and ultimate death. Death was sudden, without struggle; the machinery of life stopped gradually and quietly. *Temperature, pulse or respiratory changes were not notable,* though there was some decrease in body weight. *The H-ion concentration of the blood remained unchanged until the end.* Microscopic examination of all the principal tissues and organs of the body showed that *all were apparently normal, excepting the cells of the three vital organs, which showed marked changes—the brain, the liver, the adrenals.* In the brain, the changes in the cortex were most marked; in the cerebellum next, and least marked, in the medulla and spinal cord. Those brain cells which had entered the final stage of disintegration had lost all power of survival. Those that were on the verge of final break down could be restored by sleep. No other known agents or stimulations could produce this restoration if sleep was not one of the agents. Emotions cause a more rapid exhaustion than ordinary trauma, excepting extensive mangling of tissue, or intensive toxic stimulus, or poisoning.

In experiments with fear it was found that great changes in the cells of the brain, the liver and adrenals took place; the blood was acutely acidosed, albumen and sugar appeared in the urine; the adrenal output was increased, and the electric conductivity of the brain, the liver and other organs was altered.

Electricity may stimulate within certain limits, or in excess it produces progressive cell changes, resulting in final exhaustion.

Excision of the adrenals is followed by progressive fall of body temperature, exhaustion, its resulting cell changes, and death. No kind of stimulation or known substitute can overcome this final result.

The excision of the liver produces practically the same results.

Exhaustion from any cause is marked by a diminished conductivity of the brain and an increased conductivity of the liver. The tendency of all other tissues in exhaustion is toward a diminished conductivity, with the exception of the liver. All these findings point toward one conclusion that, both the histology, organic alterations, and the electric changes bear a direct relation to the vitality of the organism.

The proper function of the liver is essential to the work of the brain, as well as to the eliminative process of the kidneys and metabolism of the lungs; when the liver is excised, the blood becomes acid as the animal nears exhaustion. Transfusion of blood or other stimulative measures have not been able to check the resulting death. On the other hand, granting adequate circulation and respiration, *decapitation* does not interfere with the function of the liver. We must conclude therefore, that the liver derives its energy to function from the primary electric energy produced by the tissue-cells of the body, and in part from the adrenals.

The brain in itself is not an energy CREATING organ; this is meant in the physical sense, and is separate and apart from the psychic functions which are fully explained in the chapter on psychical process. This seems to conflict with the development process of the verte-

brate embryo: There the central nervous system, starting with the axial gradient, the cephalic ganglia and eyes, lead all others in development. However, on close study it is found that as soon as any neuron group or axon, or axon bundle, becomes functionally active, changes in the potential gradient occur with resulting currents, which affect the potential of surrounding cells. In other words, whereas, in the beginning the axial gradients were the primary causes of excitations, that is potential electric energy, the surrounding cells later on become the causes of excitations, or potential electric energy, and the functioning neurons are now merely transmitters.

As evidence in support of the assumption that the brain, physically, is merely a transmitter or transformer of energy derived from other sources and not a creator, and that it draws this energy or energy fuel from other parts of the body, we have the vast blood supply going to the brain; the system of paralleling arteries reinforced by the great basilar arterial distributor, the Circle of Willis, which forms such an abundant basal supply, such as no other tissue of the body has. The blood that flows up into the brain is arterial blood, and the returning stream is venous blood; in its passage through the brain large amounts of oxygen are taken out of the blood and large amounts of CO_2 are added.

The supplying arterial blood contains more sugar than the returning venous blood. A few minutes after the lungs have ceased to take in oxygen, consciousness is lost; there are no stored carbohydrates in the brain; six minutes of interruption in the blood circulation to the brain is death: As in contrast with approximately 500 minutes for muscle or tissue. The brain is more

sensitive to acids than any other tissue; in acute acidosis, the function of the brain ceases earlier than that of any other organ. According to the findings of Alexander and Cserna, the brain has a total metabolism five times greater than the metabolism of all the voluntary muscles put together, excepting when these muscles are active.

Stored carbohydrates in other cells are the source of anaerobic oxygen. They supply energy in the absence of atmospheric oxygen; they supply oxygen for neutralizing lactic acid, and for overcoming intercellular acidity; the brain cell, therefore, has within itself no stored fuel. In contrast to muscle, liver, and other tissues, the brain cell depends exclusively on aerobic oxidation. There is less protein in the brain cells that can be broken down as a protection against acidosis, than in any other cell of the body; the brain cell lacks protection against the acute carbondioxide intoxication of exertion, fever, emotion, etc. The brain cells have no power of self digestion or electro-chemical activity of their own accord, as have other cells of the organism.

In starvation, the brain practically loses no weight. It is important to note that wasting does not occur to an equal extent in all tissues and organs. The real producers of physical energy, and excess stores of food, lose most and feed other organs at their expense. Thus, the heart loses little or none, and the central nervous system loses at most 3 per cent of its weight. The fat nearly all disappears, at least 97 per cent of it being used up; muscles lose 30 per cent of their original weight, and most of the other organs suffer also in varying degrees. Taking the total loss as 100, Voit gives the loss of individual organs due to starvation as follows:

Bone ... 5.4	Pancreas ... 0.1	Brain and cord 0.1
Muscle .42.2	Lungs 0.3	Skin and hair. 8.8
Liver ... 4.8	Heart 0.0	Fat 26.2
Kidneys . 0.6	Testes 0.1	Blood 3.7
Spleen .. 0.6	Intestines .. 2.0	Other parts ... 5.0

If a brain cell is destroyed, no other brain cell can take its place. Its loss is permanent. The vast volume and distribution of blood in the liver, in the lungs, and in the kidneys provide for the rapid elimination of waste, which is necessary for the functioning of the brain; the large storehouse of sugar in the liver serves as fuel for the brain, and the blood stream carries it and oxygen to the brain. Without the chemical action of the adrenals, neither liver nor brain can function. The brain cannot work continuously, but a process of rest at intervals is necessary for it is here, no doubt, where the psychical process enters into the functioning of the physical activity of the organism, for it has been shown that when the brain ceases to function from lack of sleep, it ceases to transmit, transform or direct such energy to the vital organs as these organs require, to perform the work which makes possible the functioning of the physical brain.

In the different determinations to ascertain the actual functions and activities of the brain we have thus clearly found the fundamental causes which can impair or stop its working as well as its real functions. Lack of sleep, mental exhaustion, and faulty electro-chemical functioning of the cells, or generating organs; or injury to any body-areas, or organs having afferent nerve impulses going to the brain, and (in case of such impairments) their results and effects on different organs and the body as a whole, varies in proportion to which the directing or dynamic energy of the brain is necessary

for the proper functioning of such organs. On the other hand, neither the brain cells nor any organ nor the individual as a whole is immediately exhausted by unlimited trauma inflicted on areas cut off from a connection with the brain by blocking the nerve supply.

In a general resumé of the facts as compiled in this work, we can say this: The energy recognized as solar and planetary electro-magnetic force, under specific conditions, combines atoms according to definite laws, into combinations of molecules, protoplasms, and nuclei, which form the combinations known as cells.

These cells, by reason of their atomic (chemic difference between nucleus and protoplasm) have in themselves opposite polarity. The prevailing electro-magnetic environment of the moment is the selector, or determining factor of such original combinations; this establishes cell pattern. Each pattern possessing its own atomic individuality, thus giving the cell its selective properties, which is the basis of its future development. The opposite polarity or potential difference, with electro-magnetic energy as the external exitor factor, causes the cells to generate sufficient electric energy to enable them to absorb new atomic combinations of such quantity and kind as they require to maintain, or increase this potential difference in order to sustain themselves or multiply. In sex reproduction the cells or sperma or ovum contain, besides the original cell pattern, complex patterns representing the organism from which they become disassociated.

We cannot help but to conclude now from the amassed evidence that these cells in their process of evolutionary development, have set up an intricate network of communication (nerves). Concentrating this

network in great plexuses, which form the connecting central points, it branches out again to the specific working and generating organs, and their activities represent the energy which is the power or force that operates the physical organism. These cells, through their plexuses, organs and afferent nerve fibers, send their impulses through the cranial nerve, spinal cord and ganglia to the brain, where they are organized, directed and governed according to physical environment and needs and according to the wills and wishes of a mental process. The working organs in this whole system apparently have the parts of auxiliary power plants. Since it is evident that the cells themselves cannot generate much more energy than merely to sustain themselves, auxiliary systems, such as respiration, digestion, elimination, cardiac activity and chemical centers (the glands), are necessary to perform the work of supplying substance from which the cells can, through electrochemical action, derive additional energy. Further auxiliary systems are necessary (liver and suprarenals) to supply the brain with additional substance (fuel) and electric energy, which it requires to perform the tremendous task of motor-activity, which the body and the mind is called upon to accomplish.

Without leaving the realm of physical science, we can say: Life is an electrical phenomenon. The body as a whole, and its different organs, are power stations for specific work, and the nerves like wires, form a complicated, yet efficient network of communication between these organs. This network of communication is again equipped with sub-power stations, condensers, or tuners, to check, block, release, increase or transform the electricity flowing through them, and operating the motors of such organs as are concerned in the vital

generating process. From out this system, specific branch lines lead off to a central plexus, the brain. Some of these lines are power lines; others are merely lines of communication. Here the whole system is subject to a super-power, the directing genius whose origin or possibilities for accomplishment are beyond human conception.

What are now the most vital factors in life, the physical laws, which we understand fairly well, or the mental processes (psychical processes), of which we know next to nothing, except their manifestations?

The only way in which we know the manifestation of the psychical process is in physical life, yet, apparently physical life can exist and continue without it.

Here I beg the reader's indulgence, and his understanding of the purpose of this work, which is a study in the workings of physical phenomena as they can be perceived and understood in a purely physical sense. Before attempting this work it was a matter of the most serious consideration, to define and clearly set in my mind, the limits or boundaries which divide the physical from the psychical. In that respect it appeared to me, that a physical study of this kind can be compared to a study of law. In studying the conditions of a country, state or any social unit, we are only concerned with the laws which exist, their interpretation or meaning; the effects such laws have on a social unit, and the understanding and actions necessary to obey those laws, as well as the penalties for disobedience. In a study of this kind, I mean particularly, in order to understand each phrase, paragraph or part of each law, so as not to violate it in any way, it is not necessary to also know or study the statesmen, leaders or people, whose will enacted or created these consti-

tutions and laws. Neither is it necessary because of this to deny that something, somebody, sometime, has promulgated and set up these laws because of an urgent need for order, stability, protection, etc., necessary for constructive integration of a social organization.

It may at least be possible to set up certain gradients concerning the relative importance of physical conditions as to the maintenance of the proper functioning of our physical body. We have under another chapter fully considered the phenomena of the psychic process, and also the known influence and symptoms this process can assume over the physical activities of our system. There are a number of theories and cults which preach the entire domination of the psychic over the physical. Be that as it may, it is not our subject of discussion. Undoubtedly the psychic influences are great, and should be considered a most important item in any determination of a biologic harmonious organism as complex and highly developed as the human body.

Fundamentally, and in the final analysis the prime physical factor responsible for the harmonious working of our body must be the solar radiation and its resulting electro-magnetic condition existing on this earth. This is in turn responsible for electro-chemical conditions. If we accept this it would mean that our bodies should be in, and have proper access to, the whole spectrum of solar radiation, the magnetic stresses of the earth, pure atmospheric, and what we might term livable temperature conditions.

The demands of civilized life cause us to violate most of these requirements, more or less, so that right here in the beginning we see that civilization actually tends to weaken the foundations for the maintenance of proper body functions. Electro-therapy, with a better

understanding of true conditions, should here be able to accomplish wonderful things in that it is possible to actually reproduce the normal solar conditions on a miniature scale, as well as to accentuate or increase such electronic conditions as are lacking, and therefore correct the cause of unbalance. With a better understanding of the real relationship between electro-chemic and thermic factors, and biology, it should be possible to reestablish normal equilibrium in a body which has become unbalanced through the inroads of disease. However, it is in place here to warn against the promiscuous uses of strong electric currents of any kind, or powerful high frequency currents.

The extremely fine construction of neurons and synapses cannot tolerate more currents (a solid flow of electrons) than their size and conductivity can transmit without undue electro-chemical or thermic changes, which would destroy them.

Next in importance would seem to be the chemical substance or compositions which are necessary to maintain, build up and replenish the chemical or atomic structure of which our system is composed. In this, water should have first consideration; water is necessary to the most vital functions of the organism; water itself is a great chemical activator; water has the greatest solvent power; water has the greatest power as a catalyst; water is the only medium in which colloidal systems can be established. In fact, 85 per cent of the body is water. The therapeutic applications of cold or hot water are well recognized, but the study of their effect, in the light of decreasing or increasing nerve conductivity, stimulation, or acceleration of electro-chemical action, should reveal a much larger field of usefullness than is at present believed possible.

Foods are the next important subject for consideration. The science of dietics has been developed to the extremes of faddism, and the kind, quantity, etc., of foods to be eaten is a matter of diversified opinion. But very little as yet has been done to investigate foods and their effects in the system from an electro-chemic standpoint, and in this we also have a great field for future investigations.

We owe a great deal, in fact, the most of our knowledge of human anatomy, biology, physiology and other allied sciences, to the untiring and ever striving efforts of medical science. Yet this science has developed and uses more or less a purely chemic system of drugging, which does not take into consideration, or at least to any great extent, the electro-chemical factor. It would seem here, too, that if chemical actions were studied, (and I am gratified to say that encouraging beginnings have already been made) from the electro-chemical standpoint, astonishing results might be accomplished.

Next to be considered, and that does not signify that it is least in importance, is physical motion, or exercise. It would seem that its opposite—rest—should also be mentioned here, but this is of such universal importance that it perhaps supersedes all others, since as we have seen, the lack of sleep is as fatal as would be a lack of electro-magnetic energy; and while we can substitute or reproduce the latter, there is no known substitute for sleep. It is essential for the proper function of all organs, assimilation and elimination, that a certain amount of physical activity be maintained. A few minutes of brisk exercise will immediately increase respiration and temperature. It accelerates electro-chemical action. This might also serve to illustrate the remarkable results which certain drugless forms of

healing, i. e., the sciences concerning themselves with mechanical manipulation of one form or another, of the body, have obtained. We have seen that the touching or squeezing of a nerve will give rise to a stimulus at its termination; for the same reason, mechanical manipulation of muscle will increase vascular activity, therefore, oxidation, that is, accelerate production of electro-motive force, and its resulting endless circle of activity, which I have endeavored to explain in this work.

It is not the purpose of this work to go into specific treatises on the mechanisms of diseases, not enough practical observation from our viewpoint are available. I can, however, give some explanation on the mechanism of the physical action of infections, or poisons which cause fever.

A foreign atom, molecule, or protein, or protoplasm, enters the system either through inhalation, ingestion or absorption through the pores. This foreign intruder is of such a nature that it will go into solution with body fluids, or into atomic combinations with the cells, and in doing so upset the electro-chemic equilibrium of the body. It will result in a changing or reversal of potential in a cell, or a changed electrolysis and faulty ion exchanges. In either case, it changes the whole protoplasmic process, resulting in accelerated current of a kind, unharmonious to natural biologic function. These accelerated currents, if carried up to the brain, will cause delirium, disconcerted mental response, and a disorderly and unorganized return to the organs results. In other words, the whole system seems to lose control over itself and burns itself up. I cannot in this see, as so many investigators claim, an organized effort of nature to eliminate something. On the contrary, it is an

unorganized, unintelligent energy, unbridled, at large, bent on destruction. The natural protection against such invasions undoubtedly are the synapsis, as these in themselves are able to control and regulate this wildly onrushing current and keep it from reaching the nerves which would carry it up to the brain. If their inert resistance is great enough to prevent this, the infection or fever will subside without any material harm to the system. What then, determines the degree of severity of such an attack? Again, we must go back to the beginning, and undoubtedly it is the original axiate pattern which the invading atom possesses, and the prevailing opposing resistance, which determines the amount of disturbance it will cause in the invaded system. It also must be considered that the potential difference of the invading atom or molecule, or protoplasm must be stronger than that of the invaded cell. And here again it is in the proportion in which the invaded cell is stronger or more vital or greater in potential than the invading cell that determines the unbalance the invader can accomplish. There are no known drugs that will actually check the inroads of fever; they may alleviate and keep the temperature down, but if the invasion is strong enough and the resistance not sufficient, the patient will die. In physio-therapy and physical manipulation great results have been obtained, and when it is possible to know the first stages of such invasions and their exact location, counter currents can be produced by manipulation on the involved nerve centers which will stop the fever in its very inception.

In this work and throughout the compiling of facts and evidence I have made it a particular point not to over-step the straight and narrow limits of exact science, and to avoid anything that might be construed as

theory or speculation. Yet the fact of an evenly maintained body temperature in health, even under extreme environments, and its immediate deviations caused by the slightest abnormal electro-chemical action in the body, tempts me to voice an opinion which may seem at this time more theory than proven knowledge.

Extensive experiments in the determination of body-heat dissipation from specific areas on the body have proven without an element of dispute that a number of unbalanced or abnormal conditions can be located and determined by the use of a precision instrument designed for that purpose, and that by manipulation of a surface area at the so indicated nerve centers immediate results, i. e., normalizing of the unbalanced or diseased condition, can be accomplished.

I cannot help to speculate as to what would be the result if a science were evolved which would investigate and establish temperature standards or gradients for every functional activity in the healthy living body, as well as for bio-chemic action; comparing these with abnormal functions, might it not be possible then to establish a tabulation of diseases, based on their electro-chemic potential, i. e., electro-negative or positive variations from the normal? And might it then not be possible, besides physical manipulation of indicated areas, to create an electro-magnetic influence as a specific, according to the indicated electro-negative or positive gradient, which the abnormal function (disease) manifests through heat dissipation?

A recent editorial on the progress of science has this to say: "One fact that the latest developments of science teaches us is, that which was a fact yesterday need not be a fact today."

The Author's conclusions in Philosophizing on the

exactness of "exact science" and "Truth," is that in eulogizing, computing and proving facts, this must be understood: *Knowledge* is the *conscious understanding* of the *facts of nature.*

Exact science is: The *facts of nature identified, verified, classified and systematized by human intelligence.*

All the *facts of nature* are not known yet.

Only such *facts* as human intelligence can *identify,* have *definitions* in *exact* science.

Only such *identified* facts of nature as human intelligence can verify are in *exact science.* And only such *facts of nature* as have been *identified* as such, then verified as having been correctly identified, and finally acknowledged by human intelligence to exist as *identified* and *verified,* can be quoted as *exact science.*

The limitations then in *exact science* are the *number* of *facts known* and the *stage* or *extent* of *development* of *human intelligence* to identify and comprehend the *known facts.*

From this analysis of what actually constitutes exact science or proven facts, we see that this condition (exact science), mental or material, is an evolutionary process, accumulated knowledge, determined as the *"integration* of *atoms,"* by the *"environment* of *the moment,"* and is a *fixed* and *definite* thing *only* at any *given instant* of *time.*

Knowledge, facts, exact science are ever evolving and growing conditions in the conception of *human intelligence.*

The *Truth* is then: The established relation which the facts of nature sustain to each other and to the individual intelligence of man.

THE NEW ATOMIC SCIENCE

2ND BOOK

New Concepts of Physics

CALVIN SAMUEL PAGE
Author of *"Science of Physical Phenomena"*
"The New Physical Philosophy"
"Rx the Life Atom"

PUBLISHED BY
THE ATOMIC RESEARCH ASSOCIATION
DETROIT, MICH.
1925

NOTE

AFTER completing the manuscript of the first book and the final editing of Prof. Calvin Samuel Page's manuscript for the second book, the tremendous differences of the fundamental principles, that is, the definitions of energies and the medium through which they act as promulgated in accepted science (in the first book) and in contrast with Professor Page's new concept, and the startling fact that the final conclusions point in the same direction seems to necessitate a somewhat more thorough explanation than I have given in my foreword in the first book.

It was early in the year 1924 when, working and experimenting with certain electric modalities and seeking a scientific explanation for them, that it struck the writer very forcibly that the electronic theories of Doctor Abrams were insufficient and could never sustain the claims made for this particular method. There was no doubt whatever that certain electric modalities effect results in the human organism that cannot otherwise be obtained, but it also is true that our knowledge as to just how and in what way these modalities do effect biologically an organism is, in spite of the number of books that have been written on the subject, a profound mystery.

At that time the works of Prof. Calvin Samuel Page came to the writer's notice and I was struck immediately by the plausibility of certain fundamental laws set forth in them. Correspondence soon developed into personal contact and the ATOMIC RESEARCH ASSOCIATION was formed, for the purpose of studying, investigating and furthering the "New Atomic

Science." Also an arrangement was concluded at that time affiliating Professor Page with the Association, assuring thereby his full co-operation and the benefit of any new findings which might be developed through the criticism and experiences of other workers who were applying the new science in their practical work.

We fully realize the great risk and radical departure from the accepted in publishing Professor Page's works along side, and in a measure comparatively with accepted knowledge. We fully realize some criticism will come our way—this we invite since ultimately it must be constructive. But we also know and realize that the majority of open minded doctors and scientists will give the subject due consideration and study, and the writer personally has the pleasure of knowing a number of scientists who at first refuted the new philosophy, but after intense study and thought have come to the conclusion that no matter how far from the accepted this science is, there is nothing in it that can at this time be disqualified or disproved. On the other hand, if we take the different theories and the theses which comprise present day physical science, we know that there are at least a dozen problems and phenomena which can be and are explained in as many different ways, and the arguments as to which is the correct one are constantly flying back and forth between the investigators.

It must be of interest to the reader to know that Professor Page is a scientist of the highest caliber—a man who has devoted his entire life to the study of science, who has the strength of his convictions to the extent of refusing to commercialize his knowledge of the old science, and instead devoted his time to the study and perfection of his new discoveries for over

thirty years with practically no remuneration whatsoever. I am content to let this fact alone stand for a more detailed biography of a man whose sterling qualities and character are at once obvious when perusing his work.

We personally believe that this science will be generally accepted—perhaps not in the near future, but in the years to come, and we also have enough strength of conviction to submit it to the scientific world, as an open forum; not saying *"This is it," "Everything else is wrong,"* but simply as a text which we think has scientific value and which the reader should consider and study according to his ability and inclination.

If this study should give us the means to find a way of conquering only one of the many now incurable diseases, its purpose would be fully served.

We confidently hope and believe that this work will be accepted in that spirit and that the resulting co-operation of practicing physicians will bring about a newer and better knowledge of therapeutics.

Only a few of the many hundred reviews and opinions on Professor Page's former works can be given here, but these will suffice to indicate the importance and scope of his work.

Of particular interest should be the last article, a reprint of a statement made in 1892 in Chicago by Professor Page, which has just been verified and proven by Professor Michelson's experiment January 19, 1925.

E. PASQUÉ.

EXCERPTS FROM REVIEWS ON CALVIN SAMUEL PAGE'S FORMER WORK

"They would have burned the author at the stake a few hundred years ago. Today, he secures a sincere following among those who are anxious above all things to learn the truth."—*Seattle* (Wash.) *Times.*

"Something New Under the Sun. . . . . The New Philosophy is based upon knowledge of the older science, not upon ignorance."—*St. Paul Pioneer Press.*

"The seeming amazing impudence of one who questions all the postulates of traditional physics is changed by a careful reading of The New Philosophy."—*San Francisco Chronicle.*

"Electricity the Nervous Force is one of the most interesting chapters, and the medulla oblongata, characterized as the 'Union Station' of the Nervous System, is as true as it is picturesque in its novel terminology."—*Sioux Falls Argus-Leader.*

"Upsets common and scientific understandings by the hundred."—*Pittsburgh Dispatch.*

"The New Philosophy should be read by all who desire to learn more of the world in which we live."—*Modern Electrics and Mechanics,* New York City.

"He carries his new philosophy throughout the whole range of physics, reaching some striking conclusions."—*Washington* (D. C.) *Star.*

"Thus, matter, to him, is the one objective thing; it is not inert and, says Mr. Page, 'atomic energies are now known.' "—*Brooklyn Eagle.*

"Employing 'Rx' as the foundation of his reasoning he proceeds to develop a novel and interesting scheme of physical phenomena, which is clear and simple."—*Providence* (R. I.) *Journal.*

"I hope Professor Page may be able to effect an intellectual awakening." —*Astronomer T. J. J. See, U. S. Obser.,* Mare Island.

"Its teachings are clear, logical and definite. It will supplant the old theories."—*Prof. E. L. Coe.*

"It surely is the greatest educational development of the Twentieth Century."—*Doctors Smith* and *Richmond,* Nevada, Iowa.

"It is deserving of a Nobel Prize."—*Dr. S. S. Still,* Des Moines, Iowa.

"The general reader will find in Mr. Page's volume, in addition to his surprising discoveries, a vast amount of accurate scientific information."— *Philadelphia North American.*

" 'The New Philosophy,' by Calvin Samuel Page, is a unique and voluminous contribution to the science of physical phenomena and to the wider field of science."—*Sioux City* (Iowa) *Tribune.*

"It makes the Old Philosophy appear too antiquated for the Twentieth Century."—*Supt. S. G. Richards,* Knoxville, Iowa.

"It would seem that Professor Page's philosophy could be summed up as an explanation of all hitherto inexplicable and doubtful phenomena by a hitherto unknown element, Rx."—*Boston Journal of Education.*

To the Public: As a science reviewer of the *Chicago Tribune* for nine years I find one of the greatest surprises to be Prof. Calvin S. Page's new Physical Philosophy, completely and widely different from the present, besides the very remarkable facts that it reveals many new laws and principles, explaining Electricity and that greater marvel Gravitation, and eclipsing these superlative things, as set forth and demonstrated in his work, the discovery of the most wonderful atomic element in Nature.

Prof. Page told me just before the event was to take place as predicted by the astronomers, that Halley's Comet would not transit the sun, if the astronomers had made no errors in their mathematical work. Then he would not permit his success to be exploited in the *Tribune.*

This unusual situation plus the factor of an author unarmed by reputation, produces the unique problem of the new century; a completely new Physical Philosophy, Minerva-like, appealing to Science to be accredited, with such abundant evidence of success.

—*Ada May Krecker,* New York City.

"Professor Page's work and discoveries seem to entitle his name to appear with Aristotle, Newton and others."—*Dr. Kirkpatrick, M.D.,* in the *Des Moines* (Iowa) *News,* 1908.

Review in *Le Temps,* Paris, France, November 24, 1923

We have not the ability to analyze or even to judge the new work, "Rx the Life Atom," by M. Calvin Samuel Page, Chicago; which treats of radioactivity, gravitation, magnetism, etc., refuting the "Einstein Theory" confirmations, and founding a New Physical Science on the atom.

Is it a revelation? Is it the logical speculations of one sincere man (?) which occupies one of his chapters entitled, "The Bible Is Scientific," and demonstrates the same in 21 postulates and 35 deductions, we are not now ready to answer.

Review, *The St. Louis Globe-Democrat*

MR. PAGE DISCOVERS "RX"

"The New Philosophy: The Science of Physical Phenomena, Etc.," by Calvin Samuel Page

It is to be regretted that there is not enough space in which to tell about this new work on space, time, electricity, gravitation, repulsion, and last, but not least, and this is most important, the new atomic element, "Rx," which Mr. Page claims to have discovered. The inexplicable in nature, no matter which of its protean and otherwise multifarious forms it may take—Mr. Page calls it Rx. Other physicists have sought, from the beginning of science, to account for certain phenomena like the aberration of light, the varying density of the atmosphere, the irreducible minimum in the spectrum and the like. These men of science have tried to explain these factors sometimes on physical, sometimes on metaphysical lines, only finally to regard them according to the offhand formula of Thomas Huxley—so many walls for the surmounting of the human mind, and with each successive surmounting to find another wall with the implied inscription, "So far, O man, shalt thou go and no farther."

But man has persevered and probably erred the while. Yet these successive impedimenta have only moved him to greater efforts. Nature holds a mystery. Man thinks he holds the key. In the fitting of this key to this mystery the best minds have been busy, through these uncountable centuries (mere split-seconds of eternity). Calvin Samuel Page, making due allowance for all this immeasurable effort, newly explains in this book of upwards of 800 closely printed pages, electricity, gravitation, repulsion, sound, heat, light cohesion, magnetism, atmosphere, astronomy and nervous force. Under the latter rubric he includes man and seeks to explain the vital principle.

. . . . Every philosopher or physicist whose fame has survived the shock of time had an ether of his own. It was one thing with Aristotle, another with Descartes, and so on down the never-ending line to Clerk-Maxwell and Sir Oliver Lodge. There came a time when ether was regarded as being molecular; the latest hypothesis is that it's continuous. But whether molecular or continuous, Mr. Page is sure that it contains "Rx" abundantly. "Rx" is the Pagean key to the mystery of physics—the Bacon in Shakespeare, the unknown quantity in algebra—the x. In re x we now read Rx.

. . . . It is evident, therefore, that Rx holds in solution all the inexplicable phenomena of nature and to have discovered Rx can not be overrated as a strictly intellectual achievement. It remains to say it is not an atheistic but a deistic explanator of the universe.

Clipping from *Chicago Daily News*

NAME CHICAGOAN FOR NOBEL PHYSICS PRIZE

Calvin S. Page Nominated for Honor by Swedish Royal Academy.—Upsets Old Teachings

Radio is a color.
Sound is light.
There is no gravity.
There is no ether.
Orbits are not elliptical but circular.

Calvin S. Page, Chicago's private Einstein, has been calling attention to these and sundry other startling matters for ten years, but it was not until today that the rank and file of science paused to consider him seriously. Dr. Page's book of physical phenomena, "Rex, the Life Atom," has been nominated for the Nobel physics prize by the Swedish Royal Academy of Science. A letter from the nominating committee, praising the logical development of theories which, if generally accepted, will revolutionize scientific thought, was received with the official notification.

Atom Basis of Theory

The basis of the Page theory of matter is the atomic theory plus a universally repellant force which he calls in his formulæ "Re-X" or Rex. It is the velocity of this atom, he states, which determines its identity as light, heat, or electricity. In matter the same atom is present in all chemical combinations as a sort of hitching post for other atoms. Gravity, he contends, is not an innate attraction due to the mass of the earth, but a phenomenon resulting from the impact of the repellant force on the earth's surface.

"The study of radio has made clear to many people the close relationship between sound, light and electricity," Prof. Page said in discussing his theories. "We have sounds—vibrations simply—varying from two to 16,000

per second. On the scale above sound we find bands of extremely rapid vibrations that we classify as light and electricity. On the scale are wide zones of which we know nothing. Out of such a zone came the X-rays and it is possible that other strange forces are concealed in the present unknowns.

"It is not difficult, then, looking upon the radio vibrations as superlight, to imagine differing radio frequencies as unseen colors—which they are.

"The Rex atom is an essential postulate in any chemical combination. If we explain such compounds merely by the innate cohesive tendencies of the atoms we have to invent a new theory to explain any process which takes them out of the combination. If we recognize the presence of a repellant atom not sufficiently strong to overcome the cohesion of any other atom we can see how the elements of a chemical combination might adhere to it and not to themselves. To explain the disruption of such compounds it is then necessary only to recognize the introduction of another Rex atom, increasing the repellant force to a point that overcomes cohesion.

Corrects Old Error

"Regarding the theory of circular orbits the explanation is mathematical and covers several pages in my book. At the time Kepler formulated his law of ellipses it was generally conceded that orbits must be circular, but through an error in the equation to determine the mean lateral velocity a calculation of the space embraced in the course of a given planet gave an area that could not be circular. Arbitrarily the edges of the theoretical orbit were flattened out to make an ellipse of the same axis and the ellipse has been an established institution in astronomy ever since. My correction of the equations makes the proof of the circular orbit simple and definite.

"One astronomer—easily among the world's foremost—wrote to me that my mathematical proofs were incontrovertible but that they supported a theory too revolutionary to be adopted without considerable preparation to prevent chaos in scientific research."

Indorsing Dr. Page's book before the Nobel commission was a letter from T. J. J. See of the United States naval observatory, Mare Island, recent opponent of Einstein. Dr. Page received his degrees from the University of Illinois and taught mathematics in Iowa colleges until he came to Chicago ten years ago to complete his experiments in physics.

Clipping from *Dallas* (Tex.) *News*

"THE NEW PHILOSOPHY"

By Calvin Samuel Page. Illustrated. Science Publishing Company, Chicago.

When doctors disagree the laity has, perforce, to await the issue. To ordinary every-day readers "The New Philosophy" will carry interest, for it is written in an emphatically easy, yet concise, style; but, when it comes to having an intelligent conviction on the subject, the every-day reader has no adequate scientific knowledge to allow him to decide for or against an argument diametrically opposed to the scientific beliefs of centuries. He might, it is true, discard the view of the "luminiferous ether" of Aristotle's philosophy; but when it comes to pitting his little-science against Sir Oliver Lodge he will let the doctors fight it out. And the "ethereal void" and "nature abhors a vacuum" are terms which the philosophers instilled into his youthful mind until it will be difficult for him to imagine them as expressions meaningless in fact.

But the new philosophy of Prof. Page emphatically affirms that space is empty; that matter is limited; that there is no such thing as a universal ether; that matter is not continuous, and at any one time occupies only an infinitesimal portion of illimitable space; that the luminiferous ether "is but the warp and woof of dreams, the vast, insubstantial product of scientific mentality;" and that "the wings of heat and light, the only rivals of fleeter thought, can not brook the impediment of a single smallest mite; and since they warm all the inhabitants of illimitable space and reveal the harmony, majesty and splendor of celestial evolutions to our enraptured vision, there can be no doubt that, of every hindering thing, space is empty."

The table of contents carries the inference that Prof. Page is a wholesale heretic in accepted natural philosophy. Aside from the introduction and appendix there are fifteen chapters, with the following titles: "Fundamental Propositions," "The New Atomic Element," "New Law," "Conservation of Energy," "Law of Multiplication of Force," "The Crucial Test," "The New Atmosphere," "The New Explanation of Heat," "The New Explanation of Light" (two chapters), "The Explanation of Electricity," "The New Explanation of Magnetism," "The Explanation of Gravitation," "The New Astronomy," "Mathematical Treatment of the Orbits of the Earth, Mercury, Mars, Saturn and Halley's Comet," "The Solar System," "The Sun," "Comets," "Halley's Comet," "The Stars," "The New Explanation of Sound," "New Electricity in the Nervous Force." The appendix is devoted to an epitome of the new and old philosophies, ultra-violet rays, criticism, the Alchemist's dream.

On the principles of this new philosophy Prof. Page made the assertion in March, 1910, that, had the astronomers made no errors in their mathematical work, Halley's comet would not transit the sun—a matter which now is history; that learned as our astronomers are, the spectacle advertised did not take place. E. A. Harris, manager of the Science Publishing Company, says:

"The superlative surprise for the physicist, and the happy surprise for the general reader is the fact that, while more of the phenomena of nature are explained than ever before in a single book, the author has not used a single hypothesis." That the author is not already a renowned and accredited scientist ought not to interfere with scientific examination of "The New Philosophy," for not always have the greatest discoveries been made by the most renowned investigators."

PROFESSOR PAGE WRITES IN HIS BOOK "RX THE LIFE ATOM" AS FOLLOWS:

"I have been reading from time to time of Dr. Charles P. Steinmetz's remarkable experiments with electricity and I have wondered if he had learned of "Rx." When lo! here in the July, 1922, Popular Radio Magazine he gives such support to the banishment of the "hypothetical ether" against which I have said so much in this book that I avail myself of the testimony of this eminent engineer.

"It may be seen how persistent even an erroneous theory is when it gets into books. For October 24, 1892, in the famous Central Music Hall, Chicago, where Marshall Field's great store now is, I gave the arguments against this groundless theory that are repeated in this book from my larger work and

now reinforced by Doctor Steinmetz. Yet at this writing Prof. A. A. Michelson is on his way to Mr. Wilson to make tests on 'hypothetical waves' in this 'hypothetical ether.'"

In view of the above the following article from *The Chicago Tribune,* January 19, 1925, should be of great interest since these findings bear out the early contentions of Prof. C. S. Page.

PROFESSOR MICHELSON CHECKS UP

Æther, it will be remembered, is that supposedly imponderable stuff on which the light waves ride from star to star, and when Herr Einstein abolished it not long ago the alarm among the scientists was long and loud. Herr Einstein said he does not need the æther to explain his system of the universe, and what isn't needed to explain something in science isn't anything at all. It was a shock to science, and a revivification. To science the abolition of the æther is about as devastating as the abolition of the west wind or the monetary system is to us.

Prof. Michelson of Chicago university has been tinkering with water pipes and arc lights at Clearing, Illinois, for several months, and says now, after much fussing, that Herr Einstein isn't talking through his hat about the aether. As Prof. Michelson and Morley had a good deal to do with starting Einstein on his rampage through science his words should bear weight.

Light is not like other things. It travels 186,000 miles per second regardless of the speed of its source. It is the fastest thing we have and its speed is not affected by the speed of the thing that gives off the light. That is a huge enigma.

When you throw a potato at the waiter in the dining car in order to attract his attention, the potato, you assume, will have the speed of the car plus the velocity that you give it with your arm. That is a commonplace for potatoes, bullets, baseballs and other projectiles. But it is not true of light.

Light has a constant velocity regardless of the speed of its source, and a ray of light, unlike the potato, would not be affected by the speed of the car. While the ray of light travels from one end of the car to the other, the car would move under it a little; while for the potato the car would move relatively not at all.

The earth after all is only a large sized dining car and light and potatoes show about the same peculiarities and differences in regard to it that they do in smaller rolling stock. Aether for light to wave in, or any other medium dragged along by the earth's motion, is unnecessary, says Herr Einstein, and Prof. Michelson, so far as we can see from the great unwashed outside, seems to have proved it.

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PREFACE TO THE NEW PHYSICAL PHILOSOPHY

SINCE my initial discovery, that of the atomic element Rex, in 1889, this work has had an eventful history which concerns me more than the work itself, but what most interests the public is the truth of the new declarations which, while affirmed by myself, require the assent of the scientific world to be of force and general usefulness.

I desire first to acknowledge my deep gratitude to all past and present investigators, scientists and philosophers, even those with whom I have taken issue, for their labors have made it possible to prove the truth of my work, and where, at this late day, I have succeeded in the contest, there is no more credit than attaches to their labors and attainments.

I especially thank, and all who find pleasure and profit in this work, should join me in thanking,—

Hon. J. B. Elliott, Prof. S. G. Richards, Prof. E. L. Coe, J. V. Brann, M.D., the Misses Josephine and Luta Parsons, Miss Nora E. White, Miss Amanda Elliott, Mr. C. E. Schmidt, Dr. T. E. McLaughlin, Mr. C. E. Ripple, Mr. E. H. Gamble and Miss Lorem Donley, all of Knoxville, Iowa, who, after an acquaintance of only two months, provided the means for compiling and publishing the work, thus hastening its advent many years. And with these, contributing to the same end, are Dr. S. S. Still, Editor E. A. Nye and Mr. J. A. Wilson, all of Des Moines, Iowa, and Mr. I. A. Cole, Madison, Wis., and Mr. E. A. Harris, of Chicago, whom I wish in addition to specially thank for his able assistance in editing my manuscript.

Some scientists, without knowing of any of the discoveries and new principles of this work, have said, "Science is settled and fixed; there is no demand for a New Philosophy, and this will not be accepted." On the other hand, scientists who have become posted on the New through my lectures, discussions, and reading of my text have declared that "science will readily lay aside its hypothetical philosophy for the tangible and sense-attested explanations of the phenomena of nature."

At any rate, these are just now interesting prophecies, but contrary to the impression of the first, this work is not a challenge to the scientific progress of to-day, but it does disagree with the "theories" handed down from the past and asks a reinvestigation of them by science. Its intent is to be helpful, and from the results of years of investigation and discovery it is now possible to explain and make plain the facts surrounding present "theories" of physical phenomena, and to set out certain errors and misconceptions of early scientists that have been barriers in the paths of progress for centuries —with no intent to disparage nor minimize the value of their labors, but rather to enhance them, for their crude instruments and insufficient data are not to be compared with the perfected scientific equipment of to-day.

By reason of the accumulated knowledge the new discoveries and principles make it possible to account for all the recognized physical phenomena without resort to hypotheses, and I have set them out in form and language that make them available to the student and general reader, who are interested in new knowledge as well as the scientist.

With the hope that the discoveries and declarations of this work will prove interesting and of practical

value, and stimulate to further investigation, marking an era in educational progress, it is submitted to the considerate judgment of the scientific world.

Calvin Samuel Page.

November, 1913.

PREFACE TO NEW CONCEPTS IN PHYSICS

IT was no mild degree of personal satisfaction when parties from Detroit came to Chicago to discuss personally the therapeutic value of my discoveries, solely from reading my book, Rx The Life Atom. For I had confined its value largely to the educational field and the benefits of knowing the truth of the phenomena that concerns mere existence and then enables intelligence to create forms of usefulness and entertainment out of the same forces, for phenomena are forces.

The issue from this discussion is to be found in this book: Since the new science had to be known—be applied—and its value determined by a comparison, I took advantage of this wider publicity and have placed the essentials of the Atomic Science in this book, and outlining the possibilities of the new science for those who are in position to put them to practical tests.

This is in keeping with the history of each of my works which have had the largest patronage from the medical profession, undoubtedly because they could see the direct application of the new principles.

And since I have turned my attention directly to this phase of my work, the immediate and practical value has been greatly enhanced and widened. The *abstruce* law of the Linear Velocity in Eccentric Orbits can be known and occasionally used by astronomers, but the laws of colors of objects can be known and of use and value to everybody.

From the letters of appreciation of the new discoveries, that I have already received from doctors who have read my books, I am already assured that this method

of presenting the new discoveries in this practical and important field of human endeavor, will be heartily approved by the medical profession. For there is not a branch that it does not reach in fundamental principles.

This is not intended to be a working application of the new discoveries, in therapeutics, but it will equip all doctors to judge of the value of any technique employed in therapy. It will give a great increased equipment to meet the abnormal conditions continually seeking relief.

I have the trust and belief that this will prove beneficial to the profession and its unfortunate wards.

CALVIN SAMUEL PAGE.

February, 1925.

INTRODUCTION

IT is self-evident that the therapeutic profession is benefited and progress in the science accelerated by the discoveries of the real cause of the forces and phenomena of matter. This is already verified by the fact that doctors were the first to recognize the new physics, and also that the discoveries are facts and not theories or opinions of the author, but new knowledge that the doctor can apply.

Although the greatest new fact is the discovery of Rx and the phenomenon of repulsion, the therapeutic value of the Atomic Philosophy is not confined to Rx, but being the sole agent of repulsion, it must be continually in the lime light. The next greatest fact is the discovery of just what heat is. The reason it was not long ago discovered is the fact that the early physicists considered matter "inert," and out of this grew the "property of inertia," while inertia is only a synonym for momentum. Therefore conceiving matter to be inert, it was naturally supposed that external forces acted upon matter and produced the phenomena of matter. Hence, it was this idea of the inertness of matter that overthrew the caloric theory of heat with the present kinetic-molecular hypothesis theory. The trouble with the caloric theory was the transference of heat between bodies, and especially from the sun. Since Newton's corpuscular theory of light (a material theory) had just been overthrown and a universal ether established, the kinetic theory physicists found it easy to just hypothecate a different kind of wave of the "ether" for heat, and the problem of the transference of the heat of the sun was solved. But they had to contend

that the molecular motion heat of the sun merely produce heat waves in the "ether," which were not heat on their way but produce molecular-motion heat when they reached the earth.

The fact of cohesion with bombarding molecules did not bother these early physicists because cohesion was also considered an immaterial, external force, which would not conflict, until the amplitude of the vibrating molecules became too great. Then, since light would produce heat, the physicists began to substitute the word "energy" for "force," and conceived the transformation of energy from one form into another. The very obvious fact that it requires heat to produce light must have been neglected in their reasonings.

Energy is a modern term. My father was an eminent and very successful physician, and among his university books, I remember one small volume on "The Conservation of Forces," which traced the transformation of one force into another. The word energy did not appear in this book. There are so many forms of mechanical force where this concept did not seem to scientifically apply that they began to substitute "energy" as the source of motion which is the universal evidence of force. But this energy continued to be something apart from matter that produced the motion and force of matter. Hence they began to denote the sources of motion, as "Kinetic Energy," "Gravitational Energy," "Heat Energy," "Energy of Electricity," "Cohesive Energy," "Electrical Energy," "Magnetic Energy," "Radiant Energy," etc., but the action and produce of all of these was conceived as motion, and they began to define energy as the motion of matter. The following are a few of a large number of definitions of energy that I found in texts:

"Matter and motion are the only essentials of energy."
"Matter can possess energy only by being in motion."
"The power of doing work is called energy."
"Matter is always endowed with motion."
"The properties of matter depend upon its motion."
"All energy of whatever form is due to the motion of matter."
"A body can lose energy by giving motion to some other body."
"Mass motion and molecular motion."

The purpose of the quotations is to show that energy is something apart from matter and that it depends solely on the motion of matter as the basis of present physics, so that it may be compared with the basis of the New Atomic Science, the comprehensive statement of the basis of which is:

Energy is the inherent capacity of the atoms of matter to cohere to or to repel atoms.

The outstanding difference and all-sufficient demarcation is that while the present has two separate and distinct things, namely, matter tangible and visible, and energy, something intangible that acts upon matter and causes the production of all the phenomena of nature, matter, while the Atomic Science has only matter, the atoms of which possess the energy capacity to cause matter itself to display its phenomena.

Instead of presenting arguments against the present basis of two separate things, matter and energy, I will give the facts which confirm the basis of the Atomic Science which annuls the other.

THE NEW BASIS

There are the two fundamental, first concepts, viz., of something and nothing. The something, entity, is matter which must have form and occupy space. Hence where there is no matter there is nothing, void. Energy

must occupy space or it is void. Hence it must be matter, something.

Therefore, if energy existed apart from matter it would need to be more evident than matter itself, because, in addition to caring for itself, it would need to be able to compel inert matter to execute its phenomena. Hence, energy would need to be known, visible matter, possessing inherent energy capacity to do more than known matter possessing its one capacity to cohere or to repel, for no atoms possess both energies.

THE REAL AND KNOWN

Therefore, we know that there is something, matter, and void the absence of matter. We know the phenomena that matter displays, and since no other matter possessing energy capacity could compel matter to execute its visible, tangible phenomena with absolute, unerring precision, hence matter itself must possess its own energy-capacity to execute and display its own, numerous phenomena.

Therefore, the atomic physics locates and defines energy for the first time, and as fully as our knowledge of matter itself. Matter, we know, occupies space; we sense it by touch and sight, and in the same way we locate energy and know that it is in matter, and that the phenomena of matter is produced by this inherent capacity of the atoms of matter. It is just as real, definite and knowable as matter itself.

There is no virtue in mere motion. The notion that motion is energy cannot stand scientific reasoning. For motion or moving matter is merely multiplied force, or weight. Nothing ever results from motion until friction or collision of masses takes place as the result of contrary motions. The same is true of energy, for energy

does not act until atoms meet. And it turns out that the new notion of energy explains the origin of motion. It produces or restrains motion. Hence motion cannot be energy. We see matter by the motion produced by the energy of matter. For it is the energy of the light atom and the atoms of mass that reflect the light with the velocity-color of the object. There is no effect of light until it enters the eye, and then it is the energy action of the atoms of the retina that determines the color. It is the force, motion, the momentum of the light atom that forces it to the retina, but there it is the action of the atoms of the retina that causes the mind, the mentality, to determine the shape, size and color of the object, as white, red or some other color. Each atom does some one thing and the capacity to do this is its energy. So also matter is something that has form and occupies space. But the new energy is something more. It enables us to know the form, shape, color, weight and the capacities of the different kinds of matter. In short, it is the actions of the energies of the atoms by which we know all that we do know of matter.

It was the discovery of the repulsion energy of the atom on which the atomic physics was commenced. Cohesion has always been known, or ever since Leucippas, 500 B. C., discovered that mass matter was built up from ultimate, indivisible atoms. In modern times cohesion was considered an external force that caused the atoms of matter to cohere into mass. When the kinetic-molecular hypothesis for heat appeared, cohesion had to be supposed to act at exceedingly minute distances, for the atoms could not be in contact and in motion too. This theory supposes virtue in mere motion because of the appearance of heat. For all friction motion does result in more or less heat, but the

great variations in the quantities produced, should have revealed that there was something wrong in the "Theory." But now the discovery of exactly what heat is proves this untrue, and sustains my contention that there is no virtue in mere motion. The virtue, the product, is the action of the energy of atoms, which requires contact of atoms to act, and it is simply by motion that atoms get into contact. And the beauty of the discovery, or one of them, is the clear understanding of just what friction is.

Therefore, the exact analysis brings the conclusion that if energy, the capacity to do something, is not apart, something in the tangible, known atom, then it must be an atom itself that compels the known atoms to do what they do do. But this is unscientific. For, in the first place, it is scientific that atoms could do more perfectly from their own capacity than compelled extraneously to do it. In the second place, in most phenomena there is no place for a compelling energy atom; and in the third and most unscientific place, there would need to be many kinds of these energy atoms, or to suppose them to be protean. For that would endow them with a dual capacity. And what a superlative endowment to have a cohesive energy-atom capable of becoming a repellent energy for the purpose of explaining gases, which are the antithesis of cohesion of masses. Then, if this were done, we would be encumbered with the problem of the effects of the different energy-atoms upon one another.

WHY COHESION FOR RX?

The answer to this question not only explains this late date of the Atomic Science, but also why science has so long been really compelled to be hypothetical, and to

have forces, then energy, something apart from matter.

The first physicists in trying to explain cohesion of atoms into mass reasoned that if atoms, as gold, lead, iron, etc., cohered into gold, lead and iron mass, how could they be separated again into their atoms? Or alloys separated? And what effect would there be on their individual natures? No way was possible. Hence they concluded that cohesion was an external force that caused them to cohere. Heat could not be that force because heat destroys cohesion. Then heat was supposed to be an imponderable fluid that destroyed this invisible cohesive force. Hence, they named this fluid caloric, which was the only material force known and used. The principal effect of caloric was to destroy the supposed force of cohesion, because heat did not destroy matter, however great. Therefore they had, cohesive force, gravitational force, chemical force, etc., until modern physicists changed from "forces" to "energy," and science adopted "kinetic energy," "cohesive energy," "gravitational energy," "electrical energy," etc., and all of them introconvertible, because they were considered different forms of motion.

When I had discovered Rx with its repellent inherent energy of repulsion, and reasoned that energy must be in the known atom or be in a separate and individual atom occupying space, the riddle of the physicist was solved. All other atoms have a different cohesive strength for this one kind of atom, Rx. Hence atoms could be separated by the addition of Rx. Therefore had the early physicists solved the problem of cohesion, they would of necessity have discovered Rx and would perhaps have given it some other name.

Thus, I believe it was Walpole who said, "The correction of the errors and oversights in the explanation

of phenomena is the progress of science." The history of science shows the logical sequence that the establishing of more facts of nature increases the accuracy of the understanding of all physical phenomena. And it is also true that the understanding becomes simplified, and we wonder why it was not thus conceived from the beginning. It develops that the discovery of Rx and atomic repulsion clears up more misconceptions than any previous discovery connected with physical science.

The original and the very natural error was considering matter inert which mass matter does appear to be, and that it is acted upon by external forces. Prof. J. Dorman Steele in the introduction of his Chemistry text-book says:

> "'Dead mineral matter,' as we commonly call it, is instinct with force. Each tiny particle is attracted here, repels there, holds and is held as by bands of iron. No particle is left to itself, but, watched by an Eternal Eye, and guided by the Eternal Hand, all obey immutable law."

And Hinton wrote: "In the de-oxidation and re-oxidation of the hydrogen in a single drop of water, we have before us, so far as force is concerned, an epitome of the whole of life."

These quotations are so true and so beautifully stated, but they leave us with an intangible unlocated "Force." Now the Atomic Science comes along and locates and defines these, as the two attributes of atoms, namely, the inherent capacity of all atoms to cohere to Rx atom, and the inherent capacity of Rx atoms to repel each other upon every contact. Therefore, while mass matter appears to be inert, as Professor Steele says, the atom "is instinct with force," and each atom is perpetually using its capacity at maximum under its conditions.

Thus man has ever been seeking and discovering facts

of nature and recording them as the knowledge of mankind. In seeking to understand the facts and phenomena of matter hypotheses were used to determine more facts, and these developed into theories and theories became philosophies and when firmly established became science. Thus the discovery of Leucippas that the foundation of mass matter was the atom, was at first with him an hypothesis, and Democritus, who immediately took up the investigation, made it a theory and philosophy; by the intervening discoveries it has become a science.

CHAPTER I

EPITOME OF THE PAGE ATOMIC SCIENCE

Trinity Physical Laws

FIRST LAW—ENERGY

ENERGY is the inherent life of the atoms of matter and the source of all Force.

SECOND LAW—COHESION

Between Rx atoms and each kind and combination of all other atoms there is a different and constant strength of Cohesive affinity.

THIRD LAW—REPULSION

Rx repels its own atoms and the strength and velocity of repulsion is governed by the cohesive affinity of the substance from which they are repelled.

FUNDAMENTALS*

1. Matter is the only objective thing known.
2. Void is empty space.
3. Atoms are the smallest natural, indivisible divisions of each kind of matter in which resides the capacity, energy or life of matter.
4. Energy is the capacity of the Rx atom to repel itself or cohere to other atoms: Is unalterable and indestructible.
5. Force is the product of the action of Energy: Is productible, transferable and destructible.

*Note.—Some 80 of the probably 300 new facts, physical, mathematical and astronomical laws of the new physics, to which others will add many more. These are deductions of the Atomic Science.

6. Rx repels its own atoms and is the only repellent energy known, or used in the Atomic Science.

7. All atoms cohere with Rx with a different strength of cohesion which produces all the varying atomic weights and conductivity.

8. Energy acts and Force is transferred only by actual *contact* of matter.

9. To cohere or repel are the only inherent attributes or properties of matter; all other given properties of matter are only the conditions produced by these two attributes.

10. Momentum is the force of moving matter and was produced somewhere by the action of the Energy of matter.

11. All forces except Cohesion are the names of action forces, and are Light, Electricity, Gravitation, Magnetism, Capillary Attraction, Chemical Affinity and Momentum.

12. Cohesion is at first an action force becoming stationary with continuous contact.

13. Therefore, forces are actions and not things.

14. Heat is the constant cohering action of all atoms for or to Rx atoms.

15. There is no universal ether.

16. Matter occupies space and is only a mere fraction of endless space.

SPACE, DURATION, TIME

17. Space is merely occupied or unoccupied extension, formless, endless and eternal.

18. Duration is continuous marked or unmeasured existence, changeless, eternal.

19. Time is the measure and comparisons of the existence of things in portions of duration.

20. Events are the actions of things recorded in duration by the measures of time.

21. Duration has one dimension with three time unalterable divisions, past, present and future.

22. Therefore, matter and events are comprehended by space and duration with space and time measures.

23. Inter planetary and stellar space is a vacuum without pressure. There are temporary vacuo in the air and all gases.

FOUR STATES OF MATTER

24. Mass matter has enough Rx to maintain the atoms or molecules in stationary cohesion.

25. Liquids have too much Rx on their molecules for stationary cohesion and they yield to any force.

26. Gases are atoms or molecules so full of or surrounded by Rx that they are kept suspended by the bombardment of free Rx, and in confined gases or still air the molecules are stationary and geometrically arranged. Rx atoms as light and color, and as atmospheric magnetism is the newly discovered fourth state of matter.

27. Electrons are molecules of a gas.

28. Radiant matter is Rx as light and in its capacity of sustaining gases.

PHYSICAL FORCES

LIGHT AND COLOR

29. Light is individual Rx atoms with 140,000 to 190,000 miles per second velocity. 186,000 miles velocity given, is the measure after one reflection. Rx as light enters the eye from empty space from the object revealed.

30. Color indicates the velocity, white light having

the greatest and dull black the slowest velocity that affects the human retina.

31. Light and color are synonymous, and since light is not affected by gravitation it traverses empty space without loss of velocity.

32. Color is altered, reduced by reflections.

33. The rainbow is produced by reflection from raindrops and not by refraction.

34. All light travels in vacuo, even through the air for it is only the Rx that miss the molecules of the air that reach the eye; this is why objects become dim with distance.

35. The aurora are colors produced by the angles of reflection on the molecules of the air. The morning and evening displays of color are from the same principle.

36. It is the changes in the molecular tension that changes the green orange to yellow; and the same principle governs in the color of all objects.

37. The change in color by angles of reflection is proven by watered and changeable silks.

38. There are the two things physical and physiological light and color.

39. It is quantity of light that determines distance more than angles of perspective.

ELECTRICITY

40. Electricity is a continuous stream of Rx flowing over conductors, or with a pressure to flow as in storage batteries.

41. Positive and negative merely indicate direction of current and quantity of Rx, and positive and negative electricity are one and the same and merely indicating more or less quantity.

42. Electricity is the wholesale commerce in Rx and its phenomena are secured by utilizing this current.

43. Wireless telegraph and telephone messages are sent by electricity, but travel as light and produce electric currents in the receivers.

44. Rx separates all substances into their atoms and that is why electricity so quickly melts all substances.

45. Electricity is the Nervous Force.

46. There is only one electricity, Rx in currents, kinds are merely differences in currents from the ways in which they are produced and travel over conductors.

GRAVITATION AND MAGNETISM

47. Gravitation is the pulling stress of cohesion between Rx and the atoms of mass as Rx enters matter as light or with a slower velocity, from any source.

48. The armature of a motor is revolved by the gravitational force of Rx electricity.

49. Weight is the strength of gravitational action and since it varies with each kind of matter all atoms have a different weight.

50. Acceleration is the uniform rate of gravitational action, hence all bodies fall equally fast in vacuo, but the rate of acceleration decreases from 32.2 feet per second as the motion increases.

51. Magnetism is only special cases of gravitation due to the kinds of matter and methods of application; or matter leading Rx into currents.

52. Gravitation varies with the kind and condition of the attracted bodies.

53. All orbits should be circular by the old law of Gravitation.

54. By my newly discovered Law of the Average

Linear Velocity in orbits, orbits cannot be elliptical but are eccentric.

55. Gravitation decreases with distance slightly less than the inverse-square in the Solar System.

56. The variation of the force of gravitation causes the eccentric orbit of the earth.

57. The variation in gravitational force has produced the inclination of the earth's axis 23½ degrees.

58. The inclination of the earth's axis causes the inclination of the moon's orbit to the ecliptic that prevent monthly eclipses of the sun and the moon.

59. The orbits in the Solar System, known from wonderfully accurate measurements, prove concretely the new physics.

CAPILLARY ATTRACTION

60. Capillary Attraction is the continuous cohesive and gravitational actions between Rx and atoms in capillaries. There is no new energy or force involved.

61. It demonstrates the wonderful strength of cohesion.

CHEMICAL AFFINITY

62. Chemical Affinity is the destroying of a weak molecular cohesion by a stronger, and producing molecules of a uniform cohesive tension. There is no new energy or force involved.

63. It is solely governed by the kinds of atoms and molecules and temperature which is merely the quantity of Rx present. The atomic weights, specific gravity, specific heat, etc., prove the fundamentals of the Atomic Science.

MOMENTUM

64. Momentum is the storage of force in motion, and is the most common and universal method of storing and transferring force which is the direct product of Energy.

SOUND

65. It is an increase of the air velocity of Rx and molecules of the air that produces sound.

66. Loudness of any sound depends upon the quantity of air put into sound motion.

67. Pitch in sound is the same as color in light, the greater the increase in the velocity of air Rx the higher the pitch.

68. Quality of sound is the physiological effect of mixed velocities of sound-motion air which accounts for the endless kinds of sound.

69. The Rx motion in sound is 900,000 times faster than the rate of propagation of 1120 feet per second, which proceeds from molecule to molecule.

70. The new physics shows a score of new causes that go to determine quality of sound and explains just why no two human voices are just alike.

71. Sound is more wonderful than light, the ear than the eye.

THE ATMOSPHERE

72. The Atmosphere is maintained by the Rx from the earth, sun, stars and planets bombarding the molecules of the air. Were the Rx supply withheld five minutes the air would disappear.

73. The blue and colored skies are the electron molecules of the air and not dust as now explained. An electron is a gas molecule.

74. The air reveals space.

75. The atmosphere is stratified.

76. Near the earth only 1/6000 of the space is occupied by air molecules. At three and one-half miles only 1/12000. This explains why cold increases with altitude.

77. The earth supplies our physical needs and the atmosphere our metaphysical.

78. It is the atmospheric tension that makes the radio phenomena possible.

79. To comprehend wireless transmission one must understand Rx and the atmosphere.

THE NERVOUS FORCE

80. The human body is a perfect electrical plant.

81. It is not oxygen but Rx and the nerves that maintain the even temperature of the body of 98.6° throughout the earth and the seasons.

82. The gray matter of the brain and body are the storage batteries of Rx.

83. The gray matter of the medulla oblongata regulates the electrical tension of the lungs, hence of the body.

84. Sleep is essential for replenishing the storage batteries.

85. The mind uses Rx to execute its physical and metaphysical orders.

CHAPTER II

NEW DEFINITIONS

UNIVERSAL AXIOMATIC LAW

Contact. There is no action of energy nor effect of forces without atomic, molecular or mass contact.

The importance of this law in this place is due to the fact that present physics attempts to explain phenomena without contact, as in the cases of the theories of heat and cohesion and the electron-atom.

NEW DEFINITIONS

Matter. Matter is entity, real substance. Whatever occupies space is matter.

Atoms. Atoms are the ultimate, smallest natural divisions or parts of each and every kind of matter in which reside its capacity and nature, its life. Their size, shape and form are unknown.

Energy. Energy is the capacity of the atom to act, and there are only two actions, to cohere or cling to one another, or to repel. These are the only two inherent actions of matter used in nature.

Cohering and Repelling. Cohering and repelling I call the attributes of the atom, so as to distinguish them from the word "property" which is now vaguely used to indicate what belongs to matter.

Energy. Energy is the capacity of the atom to cohere or repel. There is no other energy known or employed in nature. This is the first time energy was ever definitely located and defined. In the dictionary it is defined merely as power, strength, etc. The

cohering and repelling of the atoms is the sole energy of nature. Atoms are indestructible and therefore energy cannot be altered or destroyed.

Force and *Forces.* When the energy of the atom acts it produces force and certain actions are termed forces, as cohesion, gravitation, capillary forces. Therefore forces are the actions of the energy of atoms somewhere and sometime. Motion, momentum is the most familiar and abundant force commonly recognized, yet the force of cohesion is perhaps more abundant, but it is a stationary force after cohering and is never seen in action.

It is common now to speak of the energy of a cannon ball and a moving engine; while they are only force, the energy of each of these is the cohesion of the atoms of which they are composed.

Here has been the great trouble with the science of the past as force was largely considered something apart from matter. Even Newton said, "Matter is the plaything of force." Something outside of matter, while force is merely matter in motion and gets its force from the action of the energy of the atoms of matter.

As I look at physics now it is a metaphysical wonder that my discoveries have so long remained secrets, and that I believed the old order so long. It will be of help to most readers to examine this point right here.

First, take matter. It must occupy space even if it has forty other definitions. Otherwise it would be void, nothing. Second, take force (leaving out energy now because it is a modern word and has supplanted "force" used by all the old and original physicists). If it is not a part of known matter, but something outside of matter, it too must occupy space, otherwise it would be void; and right here was the trouble. They treated

force, except visible motion and momentum, as something apart from matter yet acting upon matter and therefore never allowed room or space for it to occupy. In truth, force has been a nonentity until my books appeared. To me now it is axiomatic that if the known matter does not act upon the known matter as a force, then some unknown matter as a force must act upon matter and we must account for the space it would occupy. Hence had they done this the old physicists would have at once found out something was wrong and discovered just what it was, Rx, material, and given a different name.

Modern physicists in looking into the philosophy of forces saw that cohesion, gravity and capillary forces were something far different from momentum, visible moving matter, and without reasoning about space (as I have just above) they substituted energy as a foundation. They saw that every kind of work done was a result of matter in motion, accepting motion while they should have sought the cause of the motion at hand.

Thus a school text before me, after analyzing a clock weight, one body doing work on another and matter in motion concludes: "Energy may be defined as the capacity of doing work."

Then followed, since all motion can do work, "motion is energy." And since there was the old law of "The Conservation of Forces," they changed it to "The Conservation of Energy." Now it is veritable truth that all motion can do work, but I have discovered that it is also a veritable truth that every foot of motion known is the *product* of energy and therefore cannot possibly be energy.

Therefore it is self evident that if the energy of the known atoms themselves does not make them cohere

and repel, then there must be other atoms that occupy space that cohere and repel the known atoms, which is unscientific, unreasonable and contrary to all evidence and experiment. All this leads to the greatest topic in the book and the most luminous one fact in the new physics.

THE NEWLY DISCOVERED MATTER RX

Rx is the newly discovered kind of atomic matter whose atoms repel each other, upon contact, by their inherent, repulsion Energy.

Rx is of all colors, governed by the associated atoms, and is not affected by the force of gravity as are all other known atoms. Hence Rx matter has no weight.

The atoms of each kind of matter cohere to Rx atoms only, upon contact, by their own strength of inherent, cohesion Energy.

The first definition concerns only Rx matter, that it is atomic, containing inherent, repulsion energy solely for its own atoms, acting upon contact. The second definition merely states its color and weight depend upon other atoms. The third gives the relationship of all other atoms for Rx atoms, for which all other atoms possess cohesion energy capacity. I early defined Rx atoms as repelling themselves and cohesively affecting all other atoms, which appears to explain phenomena as well. But later I discovered that cohesion must be the inherent energy of the other atoms for Rx, because otherwise they would each need to possess some inherent differentiating capacity to account for as many degrees of strength of cohesion. Then it is more scientific that atoms possess the one inherent energy of cohesion than that Rx could possess the two opposite energies of repulsion and cohesion.

These definitions are a summary of the essential facts of Rx and other atoms of matter that will be developed and proven by the experimental facts and phenomena that are later examined.

I discovered Rex in 1889, and several years later adopted the name Rex as the most descriptive of its character and importance, because Rex means Chief, Prince, King. The new spelling was suggested as a differentiation and distinction, for nothing else in physics is represented by Rx. Rx is so distinctive and essential that all will be convinced that Rx is really the only significant name that could have been selected. The name is both singular and plural, referring mainly to the atom.

The first important impression one should get is, that since Rx atoms repel each other therefore there cannot be a pure Rx mass and that of necessity Rx must be on the surface of everything, because all other atoms cohere to Rx.

This is Rx the new kind of matter which furnished the name for the book, "Rx the Life Atom," but not solely for the philosophy, for the discoveries pertain to all kinds of atoms as well, and they are numerous. Thus the vastly important fact that cohesion, the most obvious force in nature, is due to the inherent energy of all other atoms for Rx atoms. Hence The Atomic Philosophy is a proper and accurate title.

A most helpful fact for the student is the discovery of and location of the phenomenon of Repulsion. It has never before been recognized in physics, while it develops that Repulsion in nature is just as fundamental as Cohesion which has always been recognized. The atmosphere displays repulsion as obviously as the earth does Cohesion.

The second important consideration is, what to expect of atoms that repel one another? In the first place it is evident there can be no mass of pure Rx because Rx atoms repel each other. This is the all-sufficient reason why the discovery has waited for the twentieth century. Therefore Rx can be retained in quantities only by it being held by the cohesion of other atoms, as in heated bodies and electrical storage batteries.

It is evident that the quantity of Rx that can be held by other masses must be governed by their relative cohesive strengths: for this repulsion must cause Rx to be continually seeking an equilibrium, just as does water, which, as it will develop, is due to Rx seeking its equilibrium, because Rx has no weight and repels in every direction. The relative quantities of Rx in substances is determined by their capacities and temperatures in consequence of its relation to heat.

The next very important deduction is that, since Rx is on the surface of every object, it can be only one layer deep. Therefore it is this Rx on the surfaces that repels and reflects the free Rx of the air and light Rx.

Since it is on the surface, it will at once be inferred, why do we not see Rx? The fact is that we do see it, but because every object reflects light Rx with the color of that object, we ascribe the color solely to the object. It is for this reason I say in the definition that the color of Rx is blue, because light Rx is reflected from the molecules of the air evenly throughout with that color, and that is why the sky is blue in clear daylight. But in the mornings and evenings the sky is quite all colors but chiefly red because the light is then of a different color velocity.

The discovery of Rx was due to a course of reasoning for an understanding of light and electricity and I came to the conclusion that there must be a self-repellent atom. Then I searched for the evidence and I found the facts given above. I discovered Rx as a principle before I knew any evidence of its existence, while now I have more scientific proof of the existence and reality of the Rx atom than of all other atoms, for it really is the only sense-attested atom known, which is in the atomic state of light. Yet it is, as matter, attested by each of the senses, and by the sensation of weight.

The importance of Rx in the phenomena of nature appears from the list of functions in which Rx is, in less and greater degrees, the chief element.

Rx is the only repellent matter known.
Rx is in every cohesive contact.
Rx is the potential for Heat.
Rx is Light with light velocity.
Rx is Color with color velocities.
Rx is the potential of Electricity.
Rx produces and propagates Sound.
Rx maintains the Atmosphere.
Rx is the agent of Gravitation.
Rx produces Magnetism.
Rx is the potential of Capillarity.
Rx is a double force in Chemistry.
Rx is the Nervous Force of animal life.
Rx is the Light-Sound of Radio.
Rx is the only inter-stellar transmitting Element.
Rx has no weight and traverses empty spaces as light without loss of velocity.

These are the phenomena in which Rx is the predominating factor due to its attribute of repulsion and

being the potential of heat. Now a longer list could be made by including other atoms due to the attribute of cohesion, for all phenomena are due to matter, atoms and the two attributes of repulsion and cohesion. A similar list can be made out for cohesion.

Cohesion of atoms is for Rx only.
Cohesion in action is Heat.
Cohesion determines the states of Matter.
Cohesion determines the properties of Mass.
Cohesion determines the conditions of Mass.
Cohesion stress is attraction.
Cohesion strength determines atomic weight.
Cohesion provides electric conductors.
Cohesion determines the color of objects.
Cohesion determines rate of falling bodies.

Therefore it is the mutual actions and inter-actions of the attributes of cohesion and repulsion that produce all the known physical forces, and all phenomena are displays of energy in action. The recognition of all phenomena is a series of mental actions. Hence the sublimity of nature increases with contemplation of the simplicity of the causes of the complex and multiplied phenomena. Not knowing what matter is, we are baffled by the mystery of the kinds of matter, and not knowing this it is surprising that the understanding of so many forces does not depend on this lack of knowledge. But it is too surprising that while there are so many kinds of matter that organic nature uses mainly only five kinds, Rx, Carbon, Hydrogen, Oxygen and Nitrogen. There must be purposes in each of the kinds of matter, and a large number have been discovered with most of the kinds. We use all of them for the special properties they possess, yet these special properties are

displayed by these two fundamental attributes: The unknown factor is the nature of each atom.

I dwell upon this necessity of recognizing the essentialness and the actuality of Rx from experience, for in my lectures, so many have said, "Too much Rx. Show me the real matter and I will accept." Then, when they convinced themselves by reason and application, they were perplexed that they had not comprehended it at once. No one has seen electricity, but its effects convince that it is something. And many have expressed the satisfaction of knowing that electricity is real matter. A charged electric wire appears the same as before, but a touch gives a shock that may be fatal. The touch convinces at once, of electricity, yet there was no change whatever in the wire; in appearance, strength or weight. The simple explanation is, Rx is in the two conditions of rest and motion, and unseen in each, because it is atomic, one layer deep on the wire.

Therefore as one becomes familiar with the atomic philosophy the evidence of the reality of Rx will become more and more positive than that of any other atom or kind of matter, and that the attribute of the inherent energy of repulsion is equally essential with that of cohesion.

Seeing is the common final evidence; and, logically, as to the evidence of seeing Rx, it is more obvious than for any other matter. Rx is light, the agent of vision, and Rx light atoms must come from the surface of the object seen, even if it is a fish under water. Hence, since all matter holds Rx, it must be that the light that reaches the eye is reflected from the Rx on the surface of the object. Since each atom and molecule holds Rx with a different strength, tension, they govern the speed of the reflection and the eye recognizes that

speed, momentum, as color and has associated it with that kind of matter from which it was reflected. Hence Rx reveals, tells, the kind of atom from which it was reflected and we have construed telling as seeing, for Rx in this capacity is the message, the color and the messenger, light.

The sudden prominence of Rx and its constant presence in the "limelight" of the book will be more agreeable to scientists if they will recognize the fact that Rx represents the function of repulsion. There are only two fundamental functions of atoms in the atomic philosophy, Cohesion and Repulsion and, because Rx is light, it makes the attribute of repulsion more prominent than cohesion. And since Rx is the only kind of atom of its class, it must appear in phenomena continually with each of the other ninety kinds and all combinations of atoms. While each are absolutely essential, repulsion is more spectacular than cohesion, because of its universality and the agent of vision, the perfect and gracious revelator of the external universe near and far removed. "Ions," "protons," "electrons," "protyle," etc., are euphoneous, but the modesty of Rx in its plain garb commends its dignity since it is the Prince of all of them, and without ostentation and with never failing integrity, ministers to vision the most essential sense of the quintet instructors and entertainers of our human mentality.

There is something of refreshing gratitude enjoying the bewildering luminosity of a cloudless day, to contemplate that it is chiefly due to tireless, ubiquitous Rx that the prodigal sun bountifully sends a fresh supply every eight minutes. And then to continue the contemplation, that its business is so important and multiplied that it employs the greatest speed known, and

makes the earth a moon to our moon and the gravitational cordage that binds the moon in her monthly vigil of our mundane sphere, as well as holding both earth and moon throughout their annual, triumphant circuit of near 600,000,000 miles around the Daystar of our family of solar orbs.

Atoms and the essential and sublime phenomena of nature resulting from the two simple but so incomprehensibly wonderful facts of their capacity to cohere or repel, and the especial and so lately discovered function of Rx repelling its own atoms with a gracious bond for all other atoms, are so impelling that I do not seem able to give rigid descriptions and let it suffice. For I crave that others, all, catch these new concepts and revel in the pleasure of their contemplation.

There is something inspiring in the knowledge of a universal element, a kind of matter so fascinating and essential here on the earth, yet at home and as gracious in the stars that illumine and adorn the depths of bewildering space. Rx is the very cause of the knowledge of their existence, and tangible evidence that they are in some ways, at least, just like our tiny globe.

Turning from immensities, unmeasured deeps and countless orbs that bedeck the dome of the celestial sphere, to the tiny mites of molecules we find Rx the essential force helping to fashion elemental mites into the myriad forms of organic and inorganic nature. For biology and chemistry deal with more and greater mysteries than does astronomy. The repellent force of Rx among atoms and molecules is as essential in producing cohesive contacts as it is in binding solar systems around their central forces.

Of course, Rx is revolutionary as the professors claim, because repulsion is a new factor, yet old as the

universe, but new because newly recognized. But does professional science desire to deal with old erroneous concepts because they are old? There are no changes in nature, but in our understanding of her laws. The first physicists were obliged to explain the great phenomena as they appeared in their functions from their limited knowledge of the fundamentals. It is a long road from the atom to the production of light. They did not have any knowledge of the atom. The atomic physics is able now to commence with the atom and therefore should be able to confirm and correct the physics that developed without these facts.

In the following pages under Special Phenomena, atoms and Rx will play more prominent parts than ever before in a physical philosophy because they are based on the functions of the atom, which, happily, account for all the facts that have been experimentally discovered about these phenomena, and reveals many new ones.

The satisfaction and unusual pleasure the studious reader will receive from the atomic physics will be that he can work out accurate understandings of so many puzzling experiences that are constantly arising. And he will find that he cannot forget new confirmations of his own. But I am afraid that many will be handicapped for some time by the old conviction of "The Ether."

RX AND THE ETHER

It is not sufficient just to say *"there is no such thing as the ether,"* because it is in all text-books and scientific works and scientists are now using it erroneously to explain electricity, wireless telegraph and telephone. The ether must be disproven and that is easy for it is

the most untenable hypothesis that ever secured such a foothold in science.

Rx as light is sweeping through space and takes the place of the ether, for space is and must be otherwise empty for known planet and cometary velocities as well as for Rx to pass through without losing velocity. I have investigated for thirty-three years and I can prove that not one single phenomenon is explained by the ether without breaking known laws and common every day experience.

Since the wireless is so popular just now and explained by the ether I will first show the weakness of the explanations. Science admits there is no affinity between the ether and matter and *cannot* be since it fills all space, for if it were there it would tear the atmosphere from the earth in a second. And some scientists to avoid this holacaust believe that the ether is so devoid of affinity that it sweeps clear through the earth like water through a sieve at 18.5 miles a second! Therefore, how *can* an instrument be affected by it? One cannot tune the light for the blind nor the violin for a deaf ear. Hence here are two dilemmas even were there such a thing as the ether, the sending and receiving.

One open inconsistency: Light "waves" of the "Ether" are estimated from 1/33000 to 1/66000 of an inch, and electric "waves" up to many miles, while matter is estimated as vibrating only at 5000 to 18,000 feet per second. Then how can it generate "waves" that travel 186,000 miles per second? But Rx repels itself from incandescence, in empty space at that velocity, while in a dark room Rx maintains the air at only about 75,000 miles per second. This velocity is a proven and the most sublime fact in all science. We

cannot comprehend it but since we experimentally prove the fact it is comforting to know how it is produced, and it is proven in Chapter IV.

This sublime velocity is absolutely essential to an understanding of the phenomena of nature and it is unthinkable that evolution evolved it out of primordial matter.

I appreciate the fact that nine-tenths of the readers have believed in the ether all their lives because there was no other explanation and that they would like to get rid of the conviction if it is wrong, hence the problem of the billion boys will make it easy.

ONE OR A BILLION BOYS

With Rx as light, a billion boys are required to pick up a billion beans in one second. The ether "waves" as light requires one boy to pick up the billion beans in a second.

The accompanying Fig. 1 represents the 40-inch Yerkes telescope lens receiving light from the sun. All the rays of light must pass the focal point F and the one small piece of ether there, the one boy, must "wave" a billion times for a billion rays passing in one second. But with Rx as light each ray is a boy and the billion merely pass that point in a second, each boy doing only one thing, while with "waves" one boy must do a billion things in the same time.

Light travels 186,000 miles a second, and a line of Rx 186,000 miles long would contain over a sextillion of Rx and they could all pass through in one second. Hence the problem is a billion times easier with Rx while it surely is impossible with "waves." But whoever believes in "waves" must accept the one boy's impossible task.

But the point F proves besides that Rx is heat, for every known substance will be melted instantly if placed at the point F. No astronomer's eye was ever at that point.

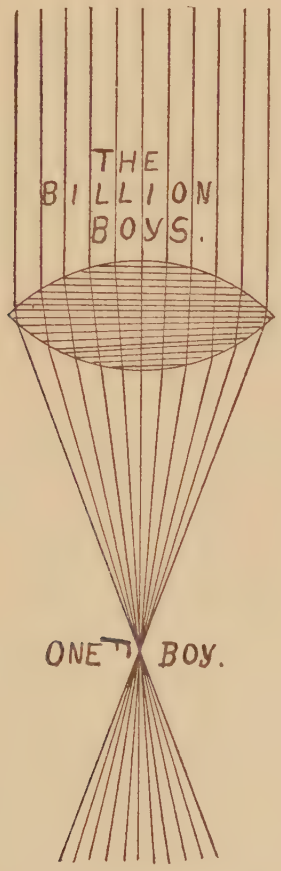

Fig. 1. Problem of the Boys

I could produce many pages on the inconsistencies of a universal ether but what I have given are sufficient for all who are anxious only for the truth and they will soon be, if not already, surprised that they ever

could have believed in such an untenable hypothesis as the ether.

It was well enough to believe in the ether when nothing nearer the truth was offered. I should thank my good fortune as well as Descartes and all the physicists who have perpetuated the hypothesis, that they did not discover some of these inconsistencies for then they would not have left Rx for me to discover.

My discovery of Rx does not discredit the discoveries of Franklin, Grimaldi, Young, Alhazen, Faraday, Volta, Roemer, Hertz, Roentgen and hundreds that could be named, but it does explain just what they did discover and really enhances their labors, and will enable others to make more discoveries to bless mankind.

Therefore, the reader can now accept Rx as a sublime reality, and when he has finished the study of this book he will know more about Rx than all the other atoms combined, will see Rx in every flower and gorgeous sunset and hear Rx in every symphony of sound. Nay! Sublimer still! Whenever he looks at Polaris he may feel the actual touch and thrilling consciousness that a real inhabitant, a divine Rx messenger has traveled for forty-four years from the Lighthouse of the northern skies through the interminable void of space to assure him of his faithful guardianship.

DEFINITIONS RESUMED

Energy and *Force.* Force is the resultant actions of the atomic energy of matter producing all cohesion of matter and called cohesive force, or the repulsion of those atoms that repel producing all gases. The first maintains the solid earth, and the second sustains the spacious, wondrous atmosphere. For the atmosphere

is the most wonderful part of the earth which maintains our bodies, while the atmosphere sustains and entertains our minds. I have discovered over twenty new things pertaining to the atmosphere and the very latest, not even given in my larger work, "The Science of Physical Phenomena," will be found in Chapter IV, "Seeing Space."

Wherever a force is observed it can be shown to be the product of the cohesion or repulsion energy of the atoms of matter, and since every force is created by the energy of matter the force can be destroyed or transferred but cannot be transformed. But the energy of the atom cannot be altered or destroyed.

Motion. Motion is merely the continuous moving of a body into adjoining space or spaces and gives momentum to the body.

This would be sufficient for motion were it not for the fact that the text-books teach that energy is matter in motion or that a body possesses energy by being in motion while it is solely force, momentum. Therefore for this error substitute the energy of the atom, at least while reading this book. This error led science into accepting the greater and really astounding error of "The Kinetic Molecular theory of heat," that overthrew the real reasonable theory of caloric, whose epitaph and memorial is now preserved in the word "calory."

Since my object is to spread the truth and banish the errors in physics, I must take note of these errors. And to be sure I am not misrepresenting science I have just reviewed two high school physics, and they say that energy is "transformed" and "molecules vibrate to produce heat." And one uses for explanation the pile driver, which will soon be examined.

This "kinetic molecular theory" of heat requires that the atoms and molecules in iron or other matter do not touch, are in rapid motion and vibrate. How is it possible then for the iron to have any tenacity? It violates the law of "Contact" that I have given, for I agree with Newton "that action at a distance is unthinkable," and that is just the same as effect without contact.

All known energy is the capacity of atoms to act, cohere or repel, and all forces are the results of their action, and all known forces, except cohesion, are motion, moving forces; no energy nor forces whatever are "transformed," and no force even is transferred except momentum; and there is no energy nor force known outside of or apart from tangible matter. Even metaphysical force results from the energy of the material.

And one professor was so pleased to banish the "kinetic molecular theory," that he wrote to me, but he added that he was glad he gave up the "ether hypothesis" before he read my book, "The Science of Physical Phenomena." Now the following will help every one to get a refreshing hold of truth from momentum and heat.

Momentum. Momentum is the product of mass, in pounds or tons, multiplied by its velocity per second, or rate of motion. If the force that hurls a bullet a mile were as quickly applied to a ton it would not move it but applied slowly would move the ton a little. Hence rate of motion is a large factor.

Therefore, a body in motion does not possess energy but force, the increase of the force of its mass is by velocity and its mass is one, unity when at rest. One pound moving five feet a second would represent five pounds of force. But there would be no change in the

pound. If any change whatever takes place by a body in motion the change is due to its contact with some other matter and new action of energy.

Hence we may conceive momentum as the amount of motion in a body, the number of spaces occupied in the equal amount of time.

Heat. Heat is the measure of the quantity of Rx in matter. It is not necessary to change the present use of the words heat, hot, cold, nor its use as to force, but there is no such thing, entity, as heat or the present concept, any more than running, walking, swimming, flying are things, but are actions and conditions of real things. So heat, cold, warm, hot, burning, combustion, are one and all merely and solely the action of the cohering and repelling *energy* of the amount of Rx atoms in matter.

Virtually Rx is heat the concept, because its repulsion overcomes the cohesion of all other atoms. We speak of heat as a thing, why then is not cold also a thing? Heat, cold, hot, warm are only terms expressing the relation and quantity of Rx in objects.

If it were possible to have a quart of Rx it would merely dissolve every substance put into it but would not harm the atoms any more than water injures the salt put into it. Just see how near the truth was Caloric, a fluid theory, which the really impossible "kinetic molecular hypothesis" theory overthrew seventy-five years ago. It is one of the qualities of Rx, one that makes it a blessing in each place of need.

Likewise there is no such thing, entity, as electricity. For electricity in all its manifold kinds and uses is only the special ways of using Rx. The reason electricity is so wonderful and perfect in its uses (and destructive) is because it is the commerce in Rx.

Rx is the divine beauty of the lily, yet it may bury it in a shroud of ashes. Rx moulds its exquisite symmetry, clothes it in its immaculate color and reveals both of these perfect harmonies to the eye and to the soul.

Atoms and the essential and sublime phenomena of nature resulting from the two simple facts of their capacity to cohere and repel, and especially the special charter of —Rx, repelling its own atoms and cohering with all others, are so impelling that I do not seem able to just give a cold definition and let it go at that, for I crave to have all catch these new concepts (for I once taught the old that I score so harshly) and secure their enjoyment and inspiration. We see, know and enjoy the laws, forces and operations that, working together, make a great city, a state, a nation, and just so these new concepts open the understanding of the home and fireside, the vast and wondrously complex and variegated earth and the evolutions out in the depths of space, and perplexity and mystery give way to a satisfying and pleasing knowledge.

I admit that motion and momentum are naturally wonderful and mysterious and, perhaps more so, has been energy and for these reasons so deeply mysterious the belief prevailed that the simple thing of motion was created with matter, co-equal, but the stranger thing that it was "transformable"; that the mere motion of a hammer was transmuted into heat; that friction motion was "transformed," while one hundred times the same motion without friction would not produce any heat. It is the strange thing that Count Rumford, the father of the "kinetic molecular hypothesis," did not investigate friction instead of motion in his experiments, for he secured heat only by producing more friction

and not motion. Since the explanation of heat from friction is so simple, evident, illuminating, yes, and refreshing, I will give it.

Rx and atoms are cohered and at rest in a piece of lead, but when it is pounded the cohesion is broken up and the Rx is released as heat, and in the operation, too, outside Rx is forced into the lead. When an axle becomes hot it is because the pressure is breaking up cohesion and releasing Rx. Hence no place in nature can be found where motion produces heat without contact and friction of matter.

As stated above, the problem of the cause of motion was so perplexing that they went back to "creation" to account for it. Therefore, since they furnish an answer to this question, I will give the two new laws of motion from my book, "The Science of Physical Phenomena," that I added to Newton's Three Laws of Motion.

Law IV. All motion is the product of the action of the energy of matter on matter at some time and place; and motion becomes the force of momentum of matter.

Law V. Every change in direction of the motion of matter, or loss or gains of motion is at the expense of other force; representing the creation or destruction of force.

The false doctrine that motion was created with matter and is indestructible but transformable, and when seemingly destroyed was merely "transformed into some other motion," caused me to work out and formulate these laws that are readily comprehended when energy and force are understood.

For example, here is one of the chief experiments to prove and support the false doctrine; the force to raise a pile driver 25 feet is not destroyed but merely "transformed" and becomes potential force in the elevated

iron, because when the driver falls it will generate the same amount of force. That does look well, but the high school student should run down the error, before he reads the explanation which verifies the new discoveries.

Steam force elevated the iron pile driver. The force of the steam overcame the force of gravity that was then acting. The force of the steam surely is destroyed for it was seen leaving the exhaust. Now, too, the force of the steam is a repellent force. To "transform" a thing, it, the thing, must change into the "transformed" thing. But the steam was not changed.

Gravity will bring down the driver with the same force; but it is new gravity, and not that holding it down against the pull of the rope (which complicates the false doctrine but verifies the new). Suppose gravity stopped when the iron was released, then it would not fall. Or, suppose there is a powerful magnet at the top that could hold the driver by not quite touching it, then it would not fall.

Hence the doctrine of the "transmutation of force" is an error. Yet the learned and most highly honored president of my university expounded this law to my then susceptible brain, because it was the prevailing philosophy. And how sophomoric I felt over my new knowledge. There is no instance in nature of transmuted energy, force or matter.

Energy is the inherent capacity, life of the atom.

Force is the action of the energy of atoms.

Inertia. There is no such thing or property of matter as "Inertia," but my dictionary says, "Inertia, inertness: the inherent property of matter by which it tends to remain forever at rest when still, and in motion when moving."

Hence the dictionary contradicts my statement, and also the fundamental propositions of this book, viz.: that cohesive and repellent energy are the only two things that inherently belong to matter, while this states that it is inert, and that "Inertia" is a property. All other properties of matter are conditions of matter produced by the energy of cohesion and repulsion.

This understanding of inertia has been the cause of more trouble to science than any other word. I ought to rejoice over it because it undoubtedly has made me a scientific author and led me perhaps into many of my discoveries. However, I am most anxious for the student to get the truth so that the errors will pass with the old scientists who perhaps cannot now change such long exploited convictions.

A body has momentum when moving and by Newton's first law of motion must keep moving in a straight line until something stops it. Hence there is no need of "Inertia." When a body is at rest it does not require anything or property to hold or keep it at rest. Place some kinds of matter at rest out in empty space where there is no gravitation, would they not remain there at rest without any property? They would possess their energy, but that would not be holding them. They could not move, or what way would they move? For there is no "up" or "down" to space. Let us suppose we were there at rest holding them, if some force came along and put all in motion the way we are moving would be down. If the force had started us in the opposite direction then that would be down.

Therefore, consider inertia a synonym for momentum and it will simplify the understanding of phenomena.

Inertia with the proper understanding of its relation

to momentum is a convenient and forceful word in literature. But I have treated it purely scientifically, for figures and metaphors are not factors in the science of material physics.

Property. The word property is so common in physics, and so misunderstood and applied that it is necessary to have it very definitely defined. In the first place conceive that the two attributes of the atom, Cohesion and Repulsion, produce every property of matter. That these two are the only real and unalterable things of matter. For example, mass is considered a property, while cohesion makes it possible; elasticity is given as a property but cohesion makes a thing elastic or non-elastic, hence elasticity does not represent a nature of matter, it is more of a condition, for iron can be made elastic and non-elastic: the same may be said of hardness, ductility, malleability and all other properties. Therefore, consider that all properties now given of matter as merely conditions produced by the only two real properties, attributes, *cohesion* and *repulsion.*

It would require several pages to correct all the false notions of property, but above is the key by which all may construct their own understandings of property and all will agree. Properties are the states, conditions, qualities and appearances of visible matter produced by the energy of cohesion and repulsion of the atoms of matter. Cohesion and repulsion are the energy that produces these properties and all force is the action of the same energy. They are fundamental and axiomatic in this book. Properties are acquired possessions of visible matter, not a nature.

Some may think and doubtless say, "He surely is mistaken as to color." But later it will be proven that the

colors of all substances and atoms are the relations between the cohesion of the atoms and Rx, and the repulsion of Rx as light, and therefore variable properties and not a nature like cohering or repelling.

Cohesion. Cohesion is the capacity of the atoms to cohere. As illustrating what I have just said above, a text-book before me says, "Cohesion is the attraction between the molecules of matter." See what trouble that would create in the class if I were a pupil, for I would ask, "What is that 'attraction'? What is it like?" For to me it must be something like the atom or molecule, have form and occupy space. And it absolutely must have the identical capacity to cohere to the molecules. Hence, why complicate our knowledge with imaginary forces without any gain?

If Rx does not repel, then some other atom similar to Rx must be present to do the same identical thing.

Therefore physics is so wondrously simplified by just knowing the truth that known atoms have the capacity to cohere in contact and that Rx atoms touching repel each other.

We have been so long, long, long in using the term force without any concept of where or what it is that it cannot be over-emphasized to insist that whenever we use it that it is something like matter or contained in matter, otherwise it would be void, nothing.

We read in the books about atomic forces, molecular forces, cohesive forces, adhesive forces as though they were different things that affected the atom, molecule, etc., but without a concept, and they were plural. Now all these are just one, the inherent energy of each atom to cohere, hence, they build themselves into molecules and masses and these different names are merely locating where the one force is acting.

Likewise of gravitational, magnetic, electric, capillary, electro-magnetic forces, plural, and not a concept of any one. Now the former are all stationary forces, they cohere and keep cohering. But all of the latter are the cohesive action with Rx in motion, hence this class is motion forces; the electro-magnet holds only as long as a current of Rx is moving and even in bar magnets there is a constant flow of Rx, and they soon lose their force by the flow ceasing, and their strength depends on the quantity of Rx flowing and temperature.

The air, steam, all gases and all explosions, gasoline, powder, dynamite, nitro-glycerine, light, sound and electricity, are all one and the same force, the repulsion of Rx. They differ and vary only with the kinds and conditions of matter.

The nervous force is included in these and is Rx-electricity flowing over the nerve-wires of the body. It even requires Rx to think with and we have to sleep to have the repulsion of Rx itself recharge the storage batteries of gray matter in the brain and body.

Gravitation. Gravitation or gravity is the force resulting from the passage of Rx through masses of matter. It is virtually the cohesive action in continuity, which results from the unequal distribution of Rx throughout the universe.

Space. Space is mere extension in three dimensions, is endless, self-existent, unalterable and eternal. This is a fertile topic in Chapter II of "Rx the Life Atom," where Einstein's concept is considered.

Duration. Duration is continuous existence, co-equal and universal with space, self-existent, unalterable, eternal.

Time. Time and times are measured portions of duration, independent of space, measured by events and instantaneous throughout all space. All events at the same instant of duration throughout the universe are simultaneous, or contemporaneous.

Since space, duration and time are the chief factors in the "Einstein Theory of Relativity," their fuller discussion is reserved for the Einstein Chapter, Chapter II in "Rx the Life Atom."

Thanks to Professor Einstein for assisting the scientific world to disown the hypothetical Ether which has been used solely because no other better foundation was offered. For this cause science has made every possible experiment during the past 300 years to prove its reality, without a sign of success.

Spirit. Spirit, according to the accepted, undebatable definition of matter, must be matter, for if it does not occupy space it is void, nothing. It is so universally considered not matter that this may shock some. But why? It must be only a higher and more refined kind of matter. May spirit not be the indwelling life of matter? Its invisibility is the source of its mystery. But so also is matter at times. Some have tried to use spirit as a force in physics but science does not recognize this.

CHAPTER III

SPECIAL PHENOMENA

THE ATMOSPHERE

THE atmosphere is the most wonderful and important objective thing and part of the earth. It is not now considered objective, but the same proof and evidence that we see any object will equally apply and prove that we do see the air, and far more than any other object. Daylight is the air, but we do not see the sun by daylight, while we do see the moon by daylight. But notice I do not say that we do not see these objects by light. Hence, the truth is, in a complete summary, no luminous object is seen by daylight, but by its own light. What, then, is daylight? It is light reflected from the molecules of the air.

Luminous objects are seen by their own light and all other objects are seen by or with borrowed light. The sun creates its own light and the moon borrows some of it to reveal its whereabouts. And to still be scientifically accurate, all objects are seen by their *own* light as truly as a luminous object is seen by its own light. For luminous and non-luminous bodies change the velocity of Rx and thereby they reveal their color which is their physical capacity to affect moving Rx. Hence objects are seen by their own light which they borrowed, usually from daylight, and changed it into their own light, because every object is seen by the Rx that reach the eye direct from the object; that miss the molecules of the air. And it is by light Rx reflected from the air that objects are seen in all cases except on a

dark night a distant object is seen by light from a lamp. In this case the light direct from the lamp is reflected direct from the object and the air is not concerned.

Therefore it is discovered how vastly important the atmosphere is in its relation to the chief phenomenon of light, and in this respect alone is a subject for a long treatise.

But a more vital relationship is revealed when we know that this Rx of the air is the Rx of life itself. Air is not for the purpose of supplying oxygen alone, as so long supposed, but Rx. This is proven by the fact that animal life has been sustained by other gases, without oxygen. Fish secure Rx from what is known as the latent heat of water and do not decompose H_2O to secure oxygen. This is the greatest new fact of the atmosphere revealed by the Atomic Science, and indeed is the most vital fact of the new science as it comes nearest to human existence, to life itself.

But the Atomic Science has revealed a fourth state of matter, that of the Atomic, for Rx is in its naked atomic state in light, sustaining the atmosphere, atmospheric magnetism and all gases. No other atom is ever alone, because no atom can ever divest itself from all Rx. Therefore, there is no such thing as absolute cold in connection with other matter. Absolute cold is in space with only Rx atoms. These last declarations cannot be understood by the reader until the subject of heat is treated, a few pages farther on.

In my first work, "The New Physical Philosophy," I enumerated twenty new facts of the air and I have discovered many since then, and the most remarkable is, that luminosity is the air.

The wonders and importance of the atmosphere will increase with the consideration of physical phenomena

by the new developments of the Atomic Science, and they will commence now with the new concepts of this world-wide and world-encircling phenomenon, the Atmosphere. For we must first know just what it is.

The Atmosphere is an unconfined gas of stupendous volume that is retained by the earth by the earth's gravitational force. All other gases used by man must be confined, otherwise they are absorbed by this world gas, which represents the third state of matter as considered in present physics.

GASES

But the Atomic Science has discovered a fourth state, so that the four states now are Solids, Liquids, Gases and Atomic, the fourth of which marks the distinguishing characterist function of the atmosphere. Gases are the most vital structures of elemental material for human existence, and the atomic state of matter in gases marks it as the most vital of the four states to life itself, and to its essential and possible functionings and adaptations. And it turns out that Rx is the very key to the perfecting of the understanding of each of the four states. For Rx is the cement, the cohesion of solids. When too many Rx atoms are present its repulsion prevents stationary cohesion and the atoms and molecules roll around one another and yield individually to every force applied, as with water; and this is the liquid state. But where there are enough Rx to surround each atom or molecule or completely fill their cohesion capacity, the repulsion of Rx on their surfaces repels them just as though the Rx atoms were alone. We can now have an understanding of just what an "electron" is, that has so long been mysteriously functioning in so many phenomena, while undefined. For these

atoms that are filled with Rx so that they cannot remain either in the solid or liquid state, they assume the gaseous state where they would (and do under some conditions) bombard one another just as science now supposes and pictures the construction of gases. These atoms and molecules are now "electrons," the third state of matter, gases. Hence there are two kinds of gases. Those made of the atoms are atomic gases, such as oxygen, nitrogen, hydrogen, etc., and molecular gases made of molecules, such as steam, air, carbonic, etc.

This is the best place to put the history and understanding of the "electron" straight. J. J. Thomson (Lord Kelvin) in 1897 gave the name "electron" to the visible displays in vacuum tubes, which is just what they are, the molecules of a gas, for in a perfect vacuum the phenomena cannot be produced, and they are made possible because of the small quantities. Alpha, beta, gamma, etc., rays and emanations are only different kinds of molecules, for each kind has a different color, as is shown and proven in Geissler's tubes. Hence, when the hypothetical theory of the atom was suggested, the "electron" of Kelvin was used. It must not be confused with Rx which is an atom with more proof than any other. The "electron" has been weighed by Millikan and molecules have weight while Rx does not, but produces all weight. We now know just what odors are for they are the electrons of the substances: molecules with such an affinity that they quickly become surcharged with Rx from the air and fly away. The importance of these electrons are at once manifest by the fact that one of the five senses is for no other purpose than detecting these electron odors.

Now these "electrons" confined would maintain themselves by bombardment alone, if there were no

other lone atoms in their confined space. But there is so much free Rx radiated from everywhere as light, heat and gravitational Rx that so bombard these electrons with such lightning velocity from all sides that the heavier "electrons" cannot move. Hence I have defined still or confined air as stationary molecules ("electrons") maintained by free bombarding Rx.

Now this new fourth state of matter is this free bombarding Rx. Whether any reader is surprised or not, I confess that I am, over the fact that this new fourth state of matter is the state most vitally connected with life itself, and ministers to life in the most beneficent, sublime phenomena of the atmosphere, light, sound and the very breath of life.

HEAT

Heat is the actual action of cohering.

Heat is the continuous cohering action of all other atoms to Rx atoms, hence, Rx atoms are merely the potential, the possibility of cohering action which is the thing Heat.

Next to the discovery of Rx and its repellent energy, this discovery is the most important of all the developments in the atomic science. The following few facts will impress this upon most readers and stimulate to a more concentrated study of this remarkable phenomenon and great, essential truth of nature.

I discovered Rx in 1889, but did not discover just what heat is until November, 1924. In my two books I defined all around the truth but did not actually conceive the thing, heat. It is my surprise that I did not discover it long ago, and a greater surprise that some one of the many disciples of Rx did not make the

discovery and point it out to me. The reason why it was not discovered long, long ago, is because the early physicists declared matter to be "inert," while it is only mass matter that is ever inert, and whenever too much atomic action takes place in a mass, there is mass action from slow expansion to violent explosion, as in powder and dynamite, earthquakes and volcanoes.

Then again: Heat could not have been discovered without at the same time discovering Rx. Therefore we shall see that every consideration and fact of heat confirms this definition of heat.

The more Rx atoms in mass the more cohering action and the hotter the body becomes, and vice versa, the more Rx taken from mass the colder the mass becomes. Therefore, cold is merely the absence of cohesive action, and cooling is the decreasing of cohesive action. Hence absolute cold that the physicists have been trying to reach, is mass or atoms devoid of Rx atoms. Of course, this cannot be attained, but the physicists have theoretically nearly reached it by estimation. It may be that by this method they may discover a quantitative measurement of Rx. For the only measures now known of Rx are those of its force.

The cause of hot bodies affecting others is the escape or release of Rx. The filament of an incandescent lamp furnishes an epitome of heat action. If, when the filament is whitest the current at the lamp could be cut off by a perfect non-conductor, the light would continue bright, and unchanged indefinitely; gradual fading is from the escape of Rx.

This fact of the filament is confirmed by thermos bottles, and could perfect non-conductors be secured they would maintain any temperature indefinitely. Thus it should be observed how important is the fun-

damental law of contact, which the "electron-atom" theory disregards and is alone sufficient to explode the theory.

With these illustrations the explanation of transference of heat by conduction, convection and radiation are readily conceived by the reader, but I must produce evidence that it really is cohesive action that is the thing, heat.

A degree of heat or calorie is the amount of heat (atomic cohesive action) that will raise 15.8 ounces of water 1°.

The calorie is a memorial of the "caloric theory" which so long prevailed, and was overthrown by the present "kinetic molecular hypothesis," about 1850.

A gram of water at 32° Fahr. gives off 80° of heat and becomes ice at 32°. The cause of this is, that the Rx given off was not in stable cohering action, and it was sufficient to allow other atoms to exert 80° of heat action.

Now the ice to become water again at 32° must take on that quantity of Rx whose repulsion for the stationary cohering Rx in the ice causes the cohered molecules of the ice to be moved around by any force, and that is the water condition of H_2O molecules. The steam condition of water molecules is when they are completely covered with Rx atoms and become a steam gas.

Latent Heat. The heat that appears and disappears in the change of the gram of ice and water is known as latent heat, and the principle holds true with every substance when changing from a solid to a liquid state. It represents that quantity of Rx whose repulsions prevent the cohesive action of the atoms or molecules from assuming fixed, stationary, cohered positions.

"Latent heat" has fallen into disuse with the physicists because it is not consistent with the "kinetic" theory. They find it convincing and easy to accept the newly discovered facts which supplant the "kinetic" theory.

Latent heat and the great, new *fact* that heat is the actual cohering action of all atoms to Rx atoms, is more obvious in the electric storage battery. For a charged battery is of the same temperature when discharged but the Rx (the discharged current of electricity) when discharged as heat would far more than double the temperature of the battery. (The discovery is so recent I have not had the time to get exact experimental data. But it is scientifically evident that it will vary with different kinds of batteries, and the purity of the materials.)

It is therefore evident that heat is actual atomic cohering, and that in the charged battery a large quantity of Rx is retained by balance repulsion by the cohesive force acting in the elements of the battery. Discharging the battery is releasing this restrained repulsion, and which proves that repulsion is not heat.

Specific Heat. The net definition is: specific heat is the relative capacities of the atomic and molecular masses of the elements for cohesive heat action.

The present texts define specific heat as the capacity of a given mass of a substance compared with the heat capacity of the same mass of water.

Therefore, the atomic capacity of substances (especially the metals) is compared relatively with the molecular capacity of water, which at a glance one can see is not very scientific; yet there probably is no better way.

TABLE OF SPECIFIC HEATS

Water	1.000	Platinum	.032
Aluminum	.212	Lead	.032
Iron	.114	Glass	.019
Copper	.093	Sulphur	.203
Tin	.056	Graphite	.218
Silver	.057	Charcoal	.241
Mercury	.033	Ice	.504
Gold	.032	Alcohol	.610
Hydrogen	3.404	Oxygen	.218

This table alone is sufficient to confirm the atomic science to a chemist, while to a layman it must reveal that atoms must be wonderful and of special natures and a key to the law of molecules.

It is observed that the specific heat of hydrogen is nearly sixteen times that of oxygen, and that if they were combined in the H_2O proportion the average specific heat would be 2.342. Therefore, it is evident that hydrogen has the greatest capacity for Rx of all the elements. This makes hydrogen the lightest, hottest and acid-former instead of oxygen, which chemists have already discovered is a misnomer.

This, while explaining why oxygen is sixteen times as heavy as hydrogen, confirms that Rx is the potential of heat, that heat is cohering action on Rx atoms and that gravity and gravitation is this atomic stress for Rx while repelled through mass, and gravitation proves that this cohesive action is continuous because every body has weight. All this is due to Rx forever seeking an equilibrium. Hence, the problem of gravitation is the source of the flow of the greatest quantity of Rx. The gravity of the earth is due to the great quantity of Rx radiated from the heated interior of the earth. The gravitation towards the sun is due to the Rx from the sun (all of which may not have light velocity) but the midnight

weight of the earth as the principal force that holds the earth to its orbit is fully explained in "Astronomical Problems" in "Rx the Life Atom." The sun's attraction affects only one-half of the earth. Hence the other one-half, midnight, has full weight, gravity towards the sun.

A scientific understanding of latent and specific heat confirms the absolute accuracy of the fundamental principles of the Atomic Science.

The table of the ratios compared with water is correct, but we have to turn our concepts squarely around. The same quantity of Rx or heat, applied to an equal quantity of water and aluminum will heat the latter five times more than the water, or what is the same thing there will be five times the amount of cohesive heat action. This demonstrates that Rx is the potential of heat and that the molecular structure of the water holds a large quantity of Rx without cohesive action.

When I explained this discovery to a friend he remarked: "Why water is a storage battery of Rx." That is just what it is, and we have at once not only an explanation of the wonderful importance of water in the economy of nature, but confirmation that Rx is the potential of heat, and that the phenomenon of heat, the thing heat, is the cohering action of the atoms of matter for Rx atoms.

Water gives off its excessive Rx slowly by contact with other atoms. It is the principle of thermos bottles, but is so practically and marvelously illustrated by the Gulf Stream. This stream gives up its stored Rx slowly by contact conduction to the cold water through which it flows, and the cold winds collect Rx by contact with the surface and delivers it to the continents and the surface, atomic heat action, warms the earth.

Wholesale Confirmation. Photography alone confirms all of the vital principles of the atomic science. 1. The atomic structure of mass by the sensitized plate. 2 and 3. Atomic energy and cohesion by taking the picture and making it permanent. 4 and 5. That Rx is material with repellent, atomic energy, by Rx as light and being atomic matter that enters into combinations with the atoms of the plate. 6. That light is velocity, because the plate is bombarded in the dark with Rx of the air but with the same tension of the chemicals on the plate, hence no change takes place. 7. That colors are velocities, because the slower velocities, from other objects than white, lodge more Rx atoms on certain parts of the plate, causing shading changes in the fixed picture. 8. When printing, the quantity of Rx passing through the glass again determines the degrees of chemical change or shading. Thus from this brief summary most readers will construct a harmonious picture of the connected principles of the new physics without having to contend with hypothetical understandings.

There are exclusive texts on the subject of heat, hence at this place is given only the controlling principles and factors that can be readily applied in every phenomena of heat. But if one wishes to get the full value of this discovery of just what heat is, he should read up the history of heat in some large encyclopedia, for it has been investigated more and passed through more theorizing than any of the great phenomena.

The supreme importance of heat will at once impel every reader to a higher estimation when he contemplates that heat even transcends light, for universal light depends upon heat. How profound the oldest scientific declaration, "there is nothing hid from the heat thereof."

SENSATION

The sensation of warmth and chill, of temperature of the body are not only sufficient evidence of the net understanding of heat, but confirmation of the fundamental principles of the Atomic Science. They are sense-attested proofs of the deductions of reason. These are further confirmed by fever. In shaking hands, the colder person has the sensation of warmth due to increased cohesive action of the molecules from the Rx received from the warmer hand which senses chill from the decrease of cohesive action from the loss of Rx. To account for these, by the "kinetic theory," the molecules must be endowed with double energy (which is now undefined) besides unreasonable conditions which breaks the Law of Contact, while actual contact is the most evident fact of the conditions. Or mere motion must be endowed with this thing, energy, while motion is unknown apart from matter.

The marvelous temperature of the human body is material evidence of the cohesion and repulsion energy of the atom of matter, and confirming the great fact, evident through all nature, that this energy is in perpetual action. It loses no force because the question, what is this energy? cannot be answered until the question, what is matter? is answered. Science has been seeking from the beginning, for the cause of motion, and here it is finally found to be the inherent capacity of matter itself. And the cause of this long delay is due to the great mistake in the very beginning of considering matter inert, because objects did not move about like animals. Now it develops that the very forces that cause men to move about are the same energies that hold objects still. (When they seem to be still.)

The flesh can be burned alike by excessively hot and cold iron. In the former the Rx goes from the hot iron, and in the latter rushes from the warm body and, accumulating at the same spot, affect the flesh alike.

This is sufficient, for the reader will take more pleasure and get more food from selecting personal evidences of the sensation proofs that heat is the cohesion of atom for Rx atoms, in actual action.

LIGHT AND COLOR

Light and color are synonymous terms in the atomic science. Light is the material individual Rx atoms with light velocity, ranging from probably 140,000 to 190,000 per second, or sufficient to effect the retina of the human eye. Since it is atomic, this velocity is in free space, even in the atmosphere, for the Rx that reveals an object finds a clear way between the molecules of the air. This is proven by objects becoming less distinct with distance because more are intercepted by the molecules.

The velocity of 186,000 miles per second is that of sunlight reduced by one reflection on the moons of Jupiter, the only possible means of measuring this fearful speed, discovered by the Danish astronomer, Olus Romer, in 1676. Hence I stated 190,000 miles because Rx light obeys the laws of motion and momentum of other matter and must lose some velocity at every reflection.

The amount of loss depends on the angle of reflection just as a thrown ball. This is shown by the rainbow, as the most acute angle checks the velocity most, to that of violet, and the most obtuse angle checks the least, which is the velocity of red light. The other colors are intermediate velocities. These facts are

observed daily by delicate colored silks that change colors by angular reflections.

Hence, colors are light and indicate velocities, which are the initial causes of the effects of different colors. The owl, bat, mole, etc., have more delicate corneas and therefore are enabled to see slower velocities that reach the retina.

The incandescence of matter is the only way in which white light can be produced, and incandescence is that condition of matter where the quantity of Rx atoms permits of maximum cohesive heat action. This degree of heat repels the Rx of the air with light velocity.

Since light is the chief subject in the chapter, "Seeing Space," these initial facts are sufficient here without causing too much repetition.

But light is the universal commerce of Rx matter, and it therefore will be found participating in more of the vital phenomena of nature than in any other, and chiefly because Rx is the potential of heat.

ELECTRICITY

Electricity is Rx repelled in circuit currents over conductors, or Rx in a stressed condition in storage batteries ready to flash over conductors when released.

This definition will be found to cover every electrical condition when one realizes that the atmosphere specially and the surface of quite all electrical conductors are constantly charged storage batteries; from these all static currents are produced. The conditions for light illumination are in a dark room except incandescence. A match uses some of the conditions, for if only the Rx of the match furnished light it would be of little use, but the air sustaining Rx strikes the crater of the match and becomes light. The whole electrical wiring,

the Atlantic cables are charged batteries of Rx. The operator in Chicago produces a potential with his key and the instrument connected in New York responds by reason of the Rx already on the wire from Chicago to New York.

For the practical expert electrician it is necessary to explain that relays are necessary because of faults in the wire and the insulation which permits of loose contact of the surface Rx and the initial force (Rx) is lost on long circuits. The higher the conductivity, smoother the wire, and better the insulation, the less relay is required, which verifies the explanation of relays.

There is only one electricity, Rx in currents, no positive and negative, just as there is only one H_2O. But there are many kinds of currents, many ways of producing them, and the currents are named and known accordingly. Positive and negative merely indicate the direction in which a current is flowing. The storage battery holds only one kind, and if positive and negative represented two kinds the alternating current of a dynamo would surely need to perform some legerdemain in lightning changes to be transformed so rapidly from one into the other. Positive is the potential or source of the current and flows to the point of least resistance which is the negative, like the mouth of a river or vent in a water tank.

Both attributes, cohesion and repulsion, function in currents; the former to hold Rx to the conductor and the latter to repel the stream to the weakest point. Conductivity, insulators and conductors by every minute and technical consideration reveal the fact that there are fundamental differences in the natures of atoms that must not be overlooked in the broad claims of the

prominent factors of cohesion and repulsion. The non-conductors are just as full of Rx and compel the current to take the easier road.

Chemical, Frictional, Gravitational and Static are the classes of currents according to the means for producing them, while all of them utilize the principle of Static, namely, the Rx on the surface of all subjects.

Chemical. In chemical action more or less Rx is released from stationary cohesion, which at once produces an electrical potential, and by providing suitable conductors and insulation it is diverted into an electrical current. Since the galvanic current does not jump the smallest gap the law of contact is forcefully confirmed. The galvanic electricity is an expensive means of procuring Rx in electrical currents.

Frictional. Frictional currents are those secured from surface Rx (static battery) by mechanical application of force, by the use of the extremes of conduction and insulation, because the action of Rx is so exceedingly rapid in reaching an equilibrium. The principle is maintaining a potential for a continuous current. The static electrical machine is constructed on these principles and is the only one that produces this current for practical use.

Gravitational. Gravitational currents are those generated by the dynamo. It is the gap between the armature and field that distinguishes it from frictional electricity, because here is where the power is required to divert the gravity Rx into electric currents. In the friction machine the cohesion of surface Rx has to be overcome, while in the dynamo it is the gravitational force between the armature and field that is used, and the name is further made more significant by the fact,

that the motor furnishes nearly as much force as is required to drive the dynamo.

The recondite evidence of the understanding of this current of electricity is found in the mathematics of the materials used in specifications for dynamos and motors of any desired capacity. These also are the profound evidences of the accuracy of the fundamental principles of the new atomic science.

It is generally understood that it is magnetic attraction that drives the electric motor. But it should be understood that there is only *one* attraction in physics, which is the stress of cohesive energy between Rx and atoms as Rx is repelled through mass. The different places and methods of utilizing this force gives the name to the attractions and although it is accurate to consider the action of the dynamo and especially the motor as magnetic, it does not make the name, gravitational electricity, less significant. It is equally accurate and appropriate as chemical and frictional, which are exact.

Rx is a commodity and force product of nature, quite as wheat and water, and the dynamo is one of the greatest developments of man for harvesting this force, and all the various uses of electricity (harvested Rx) are the consumption of this force.

Static. Static electricity are the temporary currents produced by disturbances of the surface Rx on conductors. They are countless and unnoticed, but they have suddenly become of tremendous importance and value in being the most essential in radio, while also, they are so numerous that they are one of the chief causes of trouble.

A shock is the effect of a static current over the electrical wiring of the nervous system, and they are some-

times so great as to destroy the currents of the system and result in death.

A sensitive galvanometer discloses that quite every movement, and change of relation of different kinds of objects produce static currents. For the principle is the flow, or rather rush, of Rx to an equilibrium. It is as constant as water seeking its level, but a thousand times more rapid and exceeds even air rushing into a vacuum. It is this lightning velocity to reach an equilibrium that makes radio possible and so marvelously accurate. The necessity for grounding is what brings static currents into the definition of electricity.

High Frequency Currents. High frequency currents are merely cutting up a solid, continuous current into small sections. The fearful velocity of a solid current of electricity would cause it to deliver an excessive and in most cases an injurious quantity of Rx. As it is, the quantity of Rx delivered by high frequence is somewhat determined by the rapidity of the make and break spring, or rather the quick action of the spring or the oscillations in condensers or vacuum tubes. For the same spring or condenser the higher the frequency the greater quantity of Rx delivered.

This will be a shock to most electricians that have considered this current as increasing rather than decreasing the quantity of electricity. In fact, the shock will be too great for some to see the truth. But the facts are too evident not to be finally admitted. The magnetic effect of this current must be of a sufficient difference to be noted in some cases. The principle of high frequency, in some respects, compares with the hydraulic ram, while there are modifying differences.

High frequency currents are the latest development in the application of electricity. Like static currents,

they are not sources. But static would supplant all other sources could a cheap method be found of maintaining a Rx vacuum.

MAGNETISM

Magnetism is a very special case of attraction and condition of Rx. It should be remembered that there is only one kind of attraction, namely, the cohesive stress of all atoms for passing Rx. The kinds of attraction are due to the states and conditions of matter. It does seem that the attraction of the earth for all objects (gravity), the attraction of the sun for the earth (gravitation), and a magnet holding a nail (magnetic) are different attractions, but a close investigation shows that each are solely and exactly due to the cohesive stress of the atoms concerned for Rx atoms.

There are two phases of magnetism; one atmospheric and the other metalic, and chiefly of iron mass, which appears and undoubtedly is stronger than ordinary gravity and gravitation. But this does not conflict with the fact of only one kind of attraction, for, scientifically, it should be stronger, because it is an arrangement of the atoms of the strongest cohesive energy, in a uniform action, like that of a number of horses pulling in exact unison.

It is the stress of Rx passing through mass that produces the force of attraction and in the case of gravity and gravitation there is no change produced in the arrangement of the atoms and molecules of the attracted bodies, with the *one,* most beneficent exception of that of iron atoms under special conditions. For when Rx currents are forcibly passed through iron, or when naturally in the same direction for some length of time, the iron atoms arrange themselves in lines of con-

ductors, which causes Rx to flow over them like electric currents. Thus we have an explanation of the solenoid, for it compels a current of Rx to flow through the coil according to the direction of the current, which magnetizes iron, while the current over a straight wire does not.

The atmospheric phase is an increased velocity of air Rx produced by magnets and currents of electricity over conductors. This is effective on magnets and surface Rx, decreasing inversely as the square of the distance, but the surface effect on other substances is slight and feeble.

It must be understood that the surface tension of Rx depends upon the velocity of the air Rx and is maximum in bright daylight and weakest at midnight. The tension is greatest in summer, which makes static the most troublesome in that season. Hence the magnetic increase of air velocity is governed and modified by these conditions of the air Rx.

The atmospheric phase is the chief factor in radio, but the tremendous utility of magnetism in the conveying and manipulating generated power is due to the magnetic phase. Each demonstrates that electricity is a condition, and only one of the ways of using the capacities of Rx, just as a river is one of the conditions of water. This disappointment to a few should be far more than compensated by the vast increase of new fundamental knowledge of nature that displaces hypothetical concepts.

Therefore it may be seen that magnetism, like electricity is a condition of the elements and not a thing or elemental matter. Magnets, although they come nearer to individual things, merely disclose the special property or nature of iron atoms. But it is the nature

of every atom that differentiates them, as disclosed by their atomic weights, specific gravity, quanti-valence, specific heat, color, fusion and solvents. Therefore, it may be that Rx atoms and repulsion energy for each other that their natures may be what modifies the strength of cohesion for each kind of atom. These two views are not hypothetical for there are merely two ways of considering actual facts, that apply and meet the conditions.

When we so freely admit that we do not know just what matter is, it quite displays our vanity over the vast amount we have learned about matter from matter itself. Although Swedenborg augments this knowledge, we seem to be no nearer a solution of the unfathomable interrogation of just what matter is. Therefore, we may see that time and effort should not be spent in searching for what energy is, until after we have found what matter is, because we do know that energy is the cohesion and repulsion capacity of matter.

When we contemplate the vast importance of the two phases of magnetism in human affairs; atmospheric in radio, and the metalic in the transportation of power, it is remarkable that magnetism is not employed in nature as a principle. The clearly evident design in this is shown by only one element, that of iron, being naturally magnetic, yet conditionally. For otherwise the symmetry of especially organic nature, would be materially affected. As it is, the universal force of gravity does show this effect where light and heat are diverted from equal distribution. One illustration is sufficient, that of house plants turning to the main source of light, the windows. This is confirmation also of the gravitational agency of light and heat.

The relationship and the difference of magnetism

and electricity are very distinct. Electricity is Rx atoms in currents and is possible and depends upon the difference in conductivity of the elements. Magnetism depends on the special magnetic capacity of iron atoms and air velocity of Rx. Now the two relationships are, first that currents of electricity, in certain conditions, make temporary and permanent magnets of iron and produce atmospheric magnetism. Second, that atmospheric magnetism makes and effects certain currents of electricity, while dynamic currents produce the most powerful atmospheric magnetism.

This reveals the importance and value of the discovery of the repulsion of Rx. For light depends upon heat, while heat is obtained and virtually transported by light. Only iron seems to be perfectly magnetic. Most of the experiments in electrification are purely gravitational, and due to the manipulation of Rx in electrical currents, and mainly static. Cobalt and Nichel atoms may be slightly axial, and thus display some magnetic effect from an electrical current. But bismuth and antimony seem to be oppositely affected and are thus designated as diamagnetic.

VIBRATION

Vibration is the continuous accumulation and destruction in the same body of force stored in motion. Motion and force always implies matter and in most uses are synonyms of matter.

Vibrations have been exploited as the meridian of the principles of nature. But the incongruous or humorous point in this eulogy of vibrations is that the exploiters give their reason for the potency and magic of vibration, because they are the sceptre of nature, while nature nowhere uses vibration as a principle.

Nature goes right on for she is the fountain of energy, and energy is the source of all force which is a destructible and fleeting product. The creation and use of force are concomitant. The instant energy acts matter gets into motion or makes its maximum effort to move, and does move unless restrained by a greater force, exerted or produced by some other energy.

Now vibrations are the inventions of man to use the straight-on forces of nature. They are produced by mechanism constructed of energized material; and wherever nature uses vibrations she provides the mechanical apparatus, as in the coval cords. Ah! but not in the muscles of the heart?

The pendulum is the favorite illustration of vibrations and it is the best illustration of the definition, for it accumulates and destroys the same quantity of force, motion, in each swing. It is the ever-present action of the energy of gravity that permits this display of vibration. The search for "perpetual motion" is the search for an apple which when eaten one still has the apple unchanged. Motion, a product, unopposed, obeying Newton's first law of motion, will continue forever. A wheel, which is a double pendulum, or rather a perpetual pendulum, in a vacuum, without friction, would run forever, with unchanging speed, because the energy action of the two halves exactly balance each other.

My only contention against vibration is the virtue exploited because of its use by nature, which is a natural mistake from the hypothetical "wave" error. Vibrations require at least one, and in most cases two, fulcrums as in the case of most musical instruments. These are for the purpose of utilizing the straight-on forces of nature. The most obvious cause for this universal understanding of vibration is that all musical

instruments depend upon vibrating parts, causing quite the universal belief that sound is due to vibrations of the air, which is not true, for what interminable confusion there would be in the air. Even the disturbance of two talking at once, not to cite conversations. The sounds of bullets, escaping steam, blowing, etc., are not made by vibrations, but by motion given to air and vapor molecules direct and in one direction.

Vibration is a fortunate phenomenon for the Atomic Science for it furnishes the most evident and concrete proof of Rx and its attribute of repulsion. Next to the human voice and musical instruments, the most practical use of vibration employed by man is in the dynamo. The alternating current dynamo produces a vibrating current of electricity and mechanism has to be employed to convert it into a direct current which is the natural flow of electricity, straight-on in one direction.

These conditions are due to the lightning action of Rx flowing to an equilibrium. There is one exchange and adjustment of force as the rotating armature approaches the field magnet, and a reverse adjustment as it passes the magnet. The direct current keeps the flow of Rx acting in one direction.

Therefore there is no virtue in vibration itself. Force is an instantaneous product and there is only one way to store it for later use, and that is in motion, and when motion is stopped force is destroyed. Gravitational energy creates force and stores it in increased motion of the earth from July 1 to January 1 and from then to July 1, the same energy destroys the accumulated motion. Thus it is a gigantic pendulum.

This gravitation energy of the sun was supposed to be stored as motion in the increase of vegetable matter,

and later in coal beds. But here is the difference, in the latter case motion was not stored, but the sun's force was employed in building up material structures whose energy could later be employed in creating new force. Rx and atoms in vegetation are potential force and when their energy acts and produces force it must be instantly used.

All this means that the use of vibrations must be credited to man, just the same as that for electricity and magnetism. In the next subject can be found some of the wonderful applications of vibrations, the mechanisms for which man has invented.

SOUND

Sound is the increased velocity of the air bombarding Rx, which effects the stationary positions of the molecules of the air, which move and propagate from the source of the increased velocity of Rx.

This is the physical thing, sound, and physiological or sensational sound is the effect this disturbance of the air produces in the ear by contact with the external part, the tympanum.

Sound is the most complex, wonderful and profound of all physical and metaphysical phenomena. Physical light is the very simplest, being individual Rx atoms with light velocity while sound requires Rx, velocity and other elements. Then physiological light, individual Rx and velocities go to separated portions of the retina where discrimination of velocities are recognized in the different colors, while with sound, all velocities, mingled, fall upon the tympanum, and pass over a single road with an obstruction in the nature of a gap, passes through the ear, the most delicate, complex and intricate piece of mechanism known.

Sound is now defined as vibrations, or waves of the air producing an effect in the ear. Waves in the seemingly continuous medium of the air is the universal understanding of sound, propagated like waves in the continuous medium of water. Understandings of the air and water at once disclose that waves in each cannot be alike. Water molecules touch one another, while air molecules are eighteen times their diameter apart, or one gallon of molecules in 800 cubic feet of air.

The present theory of sound is so seemingly proved, not only theoretically, but by visible experiments that confirm all the deductions, that the task of proving that sound is not ordinary waves of the air, seems hopeless. Since a school text uses eight pages in showing these waves, it would require more pages to disprove them. But when one gets a clear understanding of just what sound is, the experiments themselves are readily understood and correctly applied to what really does take place. The subject of vibration was placed before sound to show that the uses of vibrations are the inventions of man for the purpose of securing the products of the straight-on forces of nature, and especially in sound.

In daylight the tuning fork, string, bell and tympanum are all being bombarded by Rx of the air with 186,000 miles velocity, but there is no sound. The tension on both sides of the tympanum is the same. When these instruments are made to vibrate, they repel the air Rx with greater velocity which affects the molecules of the air; the molecule moves with greater velocity and repels the Rx that strike them on the opposite side, and thus the force is propagated from molecule to molecule until they reach the ear, which is affected and changes the physical sound into physiological sound. Therefore, although the instruments

vibrate, the molecules of the air do not, which they would do were the air a continuous media like water. Sound vibrates by reflections from walls and parts of instruments, but this is only a modification of physical sound after it is generated and in most cases is detrimental.

While there is only a gallon of molecules in 800 cubic feet of air, we can only imagine the vast quantity of individual Rx atoms bombarding them from every direction at fearful velocities, so that in still air the molecules are stationary. The essentialness of this structure of the air and the hopelessness of the "wave theory" of sound are most forcefully and conclusive evidence by considering the propagation of sound in high winds. They do effect sound as it is, while sound waves of only 1120 feet per second would be quite impossible. The sounds from shaking a damp and a very dry sheet of paper can be understood only by the new explanation of sound.

The full investigation of sound would quite involve and prove all of the principles of the Atomic Science, and most readers from this limited treatment will find themselves turning physicists and applying the principles to the scores and scores of common problems in sound.

LOUDNESS

Loudness of sound of any pitch depends upon the quantity of air molecules in motion. For only at the source of the sound are all of the molecules affected. This is a consequence of the new understanding, for the few Rx and molecules radiate in straight lines, and, hence, sound decreases quite inversely as the square of the distance. Light decreases exactly because it

proceeds directly to its destination from its origin or the point of last reflection.

Illumination is produced quite like the propagation of sound, by reflection of light Rx from the molecules of the air. And sound does not all proceed in a single straight line, for Rx that strikes the opposite side of a molecule at an angle starts a new line of propagation. This is why sound curves somewhat around corners. This is the chief reason why Newton would not accept the "Ether" theory of light, because light does not bend from a straight course. When the founders of the "Ether Theory," detected as slight illumination in the shadow (after Newton's death) they used it to overthrow his "corpuscular" theory. But the Atomic Science explains this illumination as a consequence of luminosity which the "Ether Theory" of light cannot explain.

Thus it is explained why sound spreads in seemingly perfect concentric spheres like waves in water. I will give one argument that proves it does not propagate as water waves or waves in a continuous medium. A speaker can be heard better and farther directly in front than at the same distance to the right or left while there should be no difference whatever by the present "theory."

PITCH

Pitch of a single sound impulse is force; greater increased velocity by the source. In a musical or continuous sound, pitch is the number of vibrations per sound, which become the measure of the force or increased velocity.

Thus pitch in sound is analogous to color in light, and is a verification of the correctness of the explana-

tion of color, for the increase in velocity of sound as experimentally seen. It is further proven by the fact that the higher the pitch of the same volume, the greater the distance the sound can be heard.

Pitch experimentally proves the Rx atmosphere and propagation of sound, while it militates against the continuous, concentric "wave" theory or wave of any kind, for wave represents force, the longer the wave the greater the force. Even increasing the elasticity does not help the "wave theory," for the greater the force the longer the wave.

A bedlam of sound is analogous to greater luminosity of light. The difference in the harmony of the two is that, while the greater the number of sources of light the greater amount of light bombardment of the molecules of the air, only individual Rx enter the eye, whereas in sound a vast number of sounds strike the tympanum in confusion.

Pitch is the most technical or erudite evidence of the velocity of sounds, because it proves that different sounds cannot be combined into harmony, and harmony proves that sounds are individual and must be properly associated to travel together.

QUALITY

Quality of sound is the physiological effect of mixed velocities of Rx in a single physical tone.

Tone is the character of every sound and quality is the chief cause of the variations in sounds. Mixed velocities in light produce many of the shades, tints and some distinct colors, which correspond to mixed velocities of Rx in tones and marks their quality. It is quite like color and form to vision. There are so many factors combined in the human face that there

are no two exactly alike. For a like reason there are so many velocities in the tone of the human voice that there are no two exactly alike. Hence we may know with the assurance of fact that Rx and the molecules of the air, produce and propagate physical sound, which in turn produce physiological sound.

"PHYSICAL AXIOMS"

THE "ETHER" DISPROVED

Axiom 1.

Matter is entity, something which has form and occupies space.

Axiom 2.

Force is matter in motion, or restrained motion or pressure.

Axiom 3.

Energy is the capacity of matter or of some kind of matter to create force or restrain motion of matter.

Axiom 4.

Force is created, propagated and transferred only by contact of matter.

Axiom 5.

Force continues as motion or pressure until destroyed by counter force or pressure produced by some other energy.

Axiom 6.

Force and force only is transferred or transported by waves in continuous matter, or by individual, projected portions of matter, which are media of force.

Axiom 7.

Every wave, impulse or disturbance in a continuous medium effects and continues to effect the contiguous

medium until the original force is dissipated and destroyed.

Axiom 8.

Every wave, impulse or disturbance in a continuous medium is affected and altered by every meeting of every other wave, impulse or disturbance in the same medium.

Axiom 9.

Every force or phenomenon transported or transferred by individual projected portions of matter is affected and altered by every collision of the individual parts at the place where they occur.

Axiom 10.

A continuous medium offers resistance to motion in receiving force (motion) and consumes the force imparted to it, in propagation.

Axiom 11.

Phenomena that are universal and everywhere the same, are propagated either by a continuous matter medium, or by individual, projectile portions of matter as a medium.

Axiom 12.

Universal phenomena have, and must have, everywhere an exact supply of initial energy to act upon and through their universal medium.

GENERAL PRINCIPLES

Proposition 1.

All kinds of matter have form and occupy space.

Conclusion.

Therefore the "Ether," if it exists, must be a kind of matter.

Prop. and Con. 2.

Every kind of matter requires force to move it. Therefore the "Ether" requires force to move it.

Prop. and Con. 3.

Each kind of matter resists motion of matter. The "Ether" resists no moving matter. Therefore the "hypothetical ether" does not exist.

Prop. and Con. 4.

The phenomena of matter is produced by matter. All phenomena is the display of force. Force is not known apart from matter. Therefore the "Ether," if it existed, would need to be matter, and display some phenomena of its own, besides being (as now) only a medium.

ETHER DISPROVED

Light and *Color*

Neither light or color can be propagating "waves" in the hypothetical, universal "Ether," because:

Prop. and Con. 5.

By Axioms 5, 7 and 11, two "waves" would diminish in size and dissipate the force in propagation, while light is unaltered from its source or last reflection, to its near or remote destination.

Prop. and Con. 6.

By Axiom 8 every "wave" of light would meet and be altered by countless other "waves," while light is unaltered, except by reflection and transmission in other media.

Prop. and Con. 7.

By Axioms 7 and 8, different "lengths of waves" for color, cannot propagate together, while colors are unaltered, the same as light of Prop. 5.

Prop. and Con. 8.

By Axioms 5, 7 and 8, other media cannot separate, but destroy motion by contact, while other media do change the colors of light without destroying light.

Prop. and Con. 9.

By Axioms 5, 7 and 8, light and heat "waves" cannot propagate together, while light is always accompanied by heat. (For heat is now considered a different "Ether Wave.")

Prop. and Con. 10.

By Axiom 9 the "Ether" is a universal medium, and by 10, receives, and consumes force in propagating motion, but light is not consumed nor altered in its medium, therefore, the "Ether" cannot account for light nor its phenomena.

Prop. and Con. 11.

Since light of the same kind from a single source varies from minimum to maximum in quantity, and since in a continuous medium "waves" of the same kind cannot vary in quantity from a single source, therefore, "waves" in the "Ether," nor waves in any continuous medium, can account for the phenomena of light.

ELECTRICITY

Prop. and Con. 12.

Electricity and all of its phenomena are confined to known, tangible matter and continuous media. Therefore, electricity cannot be "waves" in the hypothetical "Ether" as now commonly supposed.

Prop. and Con. 13.

Electricity experimentally does not require the "Ether" in understanding its phenomena, and since

electricity produces the brightest light known, therefore, it disproves the "Ether theory" and light as "waves" in a continuous medium.

MAGNETISM EXPERIMENTALLY

Prop. and Con. 14.

Magnetism has two phases; one, metallic confined to the known element iron, and one, atmospheric radiating as light, and, hence, also supposed to be "waves" in the "Ether," but since all the disqualifications of "Ether waves" for light apply equally to magnetism, therefore, magnetism experimentally disproves the "Ether theory."

BY RADIO EXPERIMENTALLY

Prop. and Con. 15.

By physical Axioms 7, 8 and 10, the meter "Ether waves" of each broadcasting station in the United States, must meet and be altered by the simultaneous "Ether waves" of every other station. Since the force from no station is affected, or altered in transmission, the force is not transferred by "meter waves" in the supposed "Ether."

BY ELECTRICITY

Prop. and Con. 16.

Since radio transmission is produced by electricity, and since radio reception generates static currents of electricity, and since it is proved by Props. 12 and 13, that electricity cannot function by "Ether waves," therefore, radio transmission cannot be effected by "meter waves" in the supposed "Ether," but must be by some medium and force associated with electricity, the phenomena of which are experimentally proved.

BY MAGNETISM

Prop. and Con. 17.

Since magnetism is associated with radio transmission and reception, and since it is proven by Prop. 14 that magnetism cannot function by the supposed "Ether," therefore, radio cannot function by a medium disqualified for magnetism, but must be through the medium in which magnetism functions.

ELECTRICITY PROVES AXIOMS

Prop. and Con. 18.

Since electricity is produced, propagated and transferred by and through known continuous media, and since all functioning currents are separate and distinct, it establishes Axioms 6, 7 and 13, and proves that the supposed "Ether" cannot function electrically nor magnetically.

RADIO PROVES AXIOMS

Prop. and Con. 19.

Since radio transmission is perfect and physically exact, and since all of the troubles developed in the reception, or receiving set, and since the receiving set functions in known continuous media on the wires and surfaces of the set, therefore, radio proves the accuracy of Axioms 7 and 8, which disqualify the "Hypothetical Ether" as the transmitting medium of any *known physical* phenomena.

RADIO EXPERIMENTALLY

Prop. and Con. 20.

Since all of the 12 Physical Axioms disqualify the "Ether" as a medium of the phenomena of Light,

Color, Heat, Electricity, Magnetism and Radio, and since radio reception experimentally proves the Axioms and Propositions of the "Ether" or of any continuous medium for the transmission of the symmetrical and harmonious force or continuous force phenomena whatever, therefore radio furnishes experimental proof that the "Hypothetical Ether" does not exist.

THE "ETHER" DISPLACED*

RX

Prop. and Con. 21.

All physical and some metaphysical phenomena prove Rx, and Rx proves all physical phenomena physically, because:

1. *Axioms:* Rx is maintained by all of the "XII Physical Axioms," naturally as consequences, rather than to meet conditions, and does not require the apology of arguments. This broad credential seems to make unnecessary all of the remaining credentials.

2. *Light:* Light is not only individual, separated Rx in empty space, with 186,000 miles per second velocity, but Rx Repulsion, for the first time, gives a scientific and natural cause for the most inconceivable fact of nature, a velocity that would carry it about eight times around the earth in one brief second. Yet many of the phenomena demand some such speed.

3. *Color:* Rx at once confirms its full competency by the simplicity and perfectly scientific explanation of color by varying velocities, which furnish the most reasonable cause of the metaphysical and the only possible measurement of these velocities. The superlatively

*NOTE—This is a new dress of the scientific facts already given in the orthodox manner: It is an affirmative display to companion the "Rhetorical Arguments Against the Ether" in the author's first work, "The New Physical Philosophy." (1913)

transitony vacua in the molecules of the air between the object and the measuring eye, reveals the need of this transcendent velocity.

4. *Heat:* The cohesive act of atoms on Rx atoms is the most comprehendible and scientific concept of the marvelous and multiplied phenomena of Heat. It discloses the amazing simplicity of nature in combining in a single operation the two most essential requirements of inorganic, and so positively demanded, by organic phenomena; cohesion and heat in one action.

5. *Gravitation:* But the bewildering wisdom of (designless) nature in combining in one action and process the sublime phenomena of Cohesion, Light, Color, Heat and Gravitation by the employment of the Repulsion Energy of Rx atoms, is the climax of proofs of the essentialness of Rx. Gravitation that chains the impetuous linear motions of ponderous spheres into the charming orbits of a perpetual Universe, to be concomitant with light and heat, is made possible by the velocity of repellent and weightless Rx.

6. *Electricity:* Electricity, although not a principle, nor an essential phenomenon in the economy and complex architecture of the universe, yet the most utilitarian, mysterious, destructive, yet the most tractable combination of essential force, is revealed as a consequence of the long hidden twain of the only two Energies of nature, Repulsion, the primal co-laborer with Cohesion, which flung the once one mighty mass of matter into gigantic fragments, and then bound them together as a universe of perpetual orbits, under the gentle but all sufficient force of gravity, concomitant actions of atoms and Rx, bestowing their honors under the mysterious cognomens of Cohesion and Repulsion. What a credential Electricity tenders as sponsor for Rx.

7. *Magnetism:* And nature further revealed her perfect unselfishness in the construction of the universe, for knowing the all essentialness of the gravitational force, devised magnetism for the special use of creative intellect. And in the very simplest way by providing iron atoms, which by the Repulsion of the Rx, special control of this universal force could be utilized by creative intelligence. And, like electricity, not essential to the mechanical operation of celestial orbs, made them together co-laborers in the difficult harvest of potential Rx. Therefore, the two energies of nature, the sources of all forces, in the special phenomena of Electricity and Magnetism, are combined to gather and distribute Rx the potential of every force.

8. *Atmosphere:* The solid earth is the primal, essential foundation, the quarry and granary of elemental material, and in every mite of which, Rx is a factor and force. Cohesion is the builder and sustainer of the material globe, but turning to the Atmosphere Repulsion is its sustaining force and Rx is its controlling element and force, which make of it the most marvelous and utilitarian structure known, or conceived as existing among the spheres of space.

9. *Chemistry:* When one contemplates all else, analyzes the lily; turns from the amazement of the flaming chariots of the sky, and enters the laboratory of nature, in which and out of which issue all the objects of utility, instruction and entertainment, versatile and majestic Rx is found busiest among the workers. For while Rx is host in displaying the external universe to impressionable intellect, it is in the laboratory, chief in building and rebuilding the ever-changing structures of nature. Rx is the key to the wonders of Chemical-Affinity.

10. *Cohesion:* There are ninety-three fundamental elements, while each of the other ninety-two sometime must be as Milton wrote of his blind daughter, "they serve who only stand and wait," Rx is the ever busy one, the perfume of the rose and the cohesion of the mighty cables that sustain a Brooklyn bridge. But its importance and fascinating character is revealed by the cohesion of every atom alone for Rx.

11. *Repulsion:* Rx and Repulsion are one.

12. *Energy:* One is at sea! one is lost! before the unsolvable problem of Energy. Cohesion and Repulsion are known capacities of matter. This is established knowledge of matter and they have been made known by Energy, but the revelator, Energy, has remained concealed in the chambers of matter, and when it is discovered what matter is, it may reveal the Energy that withholds its identity, while bestowing the marvelous capacity of Repulsion upon Rx.

13. *Force:* All of the phenomena of the universe represent Force, and mankind has ever been searching for the cause of motion, but never got any farther than to name it Force. And now we have only arrived at the source and named it the Energy of the atom. Hence all Force becomes the product of Energy, and will be disclosed with the discovery of what Matter is.

14. *Nervous Force:* The climax of utility, versatility, wonderment and sublimity of the offices and functions of Rx is reached in knowing that Rx is that all-mysterious, active and initial force of human life, the Nervous Force. This is the force that executes and transmutes inscrutible thought into visible, cognizable motion; design and desire into achievement; whose dextrous execution seems simultaneous with the command. Whatever the complexity and refinement of the

mechanism of mentality that issues thought, Rx is there to give it birth and reveal the reality of invisible personality. After one has felt the touch of the velvety texture of the rose, inhaled its refreshing aroma and thrilled over the matchless glow of color; after one has thrilled over the music of pulsating nature; over the melody of a favorite song; over the raptures of mingled harmonies of the oratorio, or the deeper thrill of a beloved voice; and after surveying all of the splendors of the canopy of the vaulted sky, one comes into the presence of the tiny mite of matter Rx and realizes that it is not only the key and potency of the material mechanisms, inspiring contemplation, but to the thought that has transmuted all into sentient being, one bows inexpressible gratitude to the majesty of potential Rx, that by the Nervous Force transmutes the physical into the metaphysical.

Sound: Radio: The crowning wonderment is revealed, that while this elemental Energy (Force) has wrought and reigned from the dawn of the universe, it falls to the lot of the accumulated product of the human intellect, in Radio, to present the experimental credentials of the personality and reality of sublime Rx.

CHAPTER IV

SEEING SPACE

LUMINOSITY IS SPACE

THIS must be to the reader a unique chapter in this book. It may be recalled Professor Einstein stated that we, or he, could have no conception whatever of space, and herein I propose to demonstrate that we actually see space more than any other thing. And it will become so obvious that we will wonder why it was never before so detected.

Because of this situation and the importance of the subject, the reader can do me a great favor, with even more profit to himself, if he will just please perform the following easy experiments before reading a word of the text. And it is psychological and practical in more than one way. They will ward off any possible mental prejudice and create an appetite for the text. They will also afford an opportunity to frame personal explanations of the experiments and it will prove gratifying if the reader anticipates those given in the text or be even more accurate.

First, sit before a bright light with eyes closed and one will still have a sensation of light, sight, vision, but images will be lacking; except as the head is turned the bright light may be located. Closed eyes in daylight prove that light is physical sensation. Were the eyelids transparent the rays would not be broken and objects would be seen. The eyelids are translucent like white glass.

Second, wave the hand or a fan rapidly before the

light and if the light is strong one will be able to note changes in color. See how many can be distinguished. If the light is small and bright its image may be seen.

Third, around the middle of the day, facing the sun and looking down just ahead, winking the eyes rapidly, one will see the lower colors first, violet, blue, green and finally a deep red. Looking into a shadow or on cloudy days the red cannot be produced, while in summer the most vivid red can be secured. All objects will assume these colors which will be later noted in argument.

For a fourth experiment, look at a more or less distant bright light, and preferably at night, squint the eyelids and observe the streamers of colored light coming partly, and even all the way, from the light to the eyes. See how they disappear with the eyes wide open. This is a beautiful problem to work out and compare with the explanation given later. Looking at a bright mid-day sun, with the eyelids closed, proved to Dr. Robert T. Aiston that light and color could not be "Ether waves," and that they are produced by the velocities of Rx Atoms.

In order to conclusively prove that we see space as truly as objective things I will need to give some new things from my "New Physical Philosophy" that are not found elsewhere, and I cheerfully do this to try to add value to this book. The first important thing is to secure a correct conception of the atmosphere.

ATMOSPHERE

The molecules of the air are composed of four nitrogen and one oxygen atom held together by Rx atoms and with Rx atoms on their spherical surfaces. These molecules, "electrons" as already explained, are arranged in strata and columns and in still air are

stationary. They are held stationary by the free Rx bombarding them from all sides, for since they are enveloped in Rx atoms, the free Rx must be repelled, and which are the sustaining force of the air. I will now give known facts to prove these declarations.

In 800 cubic feet there is one gallon of liquid air, hence these molecules in the gallon had to be eighteen times their diameter from one another when occupying the 800 cubic feet space. To liquify this quantity it has to be compressed and Rx drawn off by cooling, proving there were free Rx present and an extra amount on the molecules. But a strictly scientific proof for the molecules being stationary and not bombarding each other is the fact that the air could not be transparent only for a short distance, and possibly the sky would appear not more than 100 feet away. The thermos-bottle and air spaces are conclusive proof that the molecules do not bombard, for they would soon lose their heat and would become conductors, while confined air is a non-conductor. But still nearer home is, still air in cold weather seemingly is less cold, and still closer, fanning oneself to be cool shows that the molecules must be forced into contact with the face to collect Rx, which is now the annoying heat so desirable on the cold "still day."

A cylinder with a base of 100 square feet and 8 feet high contains 800 cubic feet of air, or one gallon of air molecules. If a plunger is fitted to the cylinder the air will support 276,000 pounds. If the cylinder is made large enough so that there is only one-fourth of an inch of air beneath the plunger, the air will support 82,944,000 pounds.

This is impossible with the present theory of the molecules bombarding, but with the fact of Rx it is

easily reasonable, for there are quadrillions of times as many Rx as there are molecules. Hence the reader may know assuredly that Rx is the sustaining force of the atmosphere.

Clouds, fogs, cigar smoke in a still room floating in strata and heat waves on the prairie in summer prove that the air is stratified. I could adduce much more, but I merely give enough concrete common evidence to relieve the reader from accepting unqualified new declarations. For all of the new knowledge given in this book has been accepted and is being used in schools where known.

LIGHT—COLOR

Light Is Color and Color Is Light

In giving the new explanation of light I desire it to be noted how logically it follows with concrete facts for every factor without the slightest requirement for an hypothesis, while each special feature of light with the present "theory" requires a new hypothesis, with perhaps a score for starting the "theory."

DEFINITION

Light is the individual Rx atoms moving through free space at the approximate velocity of 186,000 miles per second, decreasing for the colors down through white, red, orange, yellow, green, blue, indigo, violet to black of probably 140,000 miles per second.

These velocities are produced by the incandescence of various substances and secured by the reduction of velocities, indicated by the laws of the Color of Objects.

Rx is the cohesion of solids, excessive Rx produces fluids and an overabundance, all gases. Combustion

is the addition of Rx to solids, now understood as heating, which proceeds through degrees until incandescence is reached, graphically seen in converting ice into steam. Now through these changes color and light have been witnessed and the incandescence of most substances produces white light, but the lower colors have been passed which are detectable in many substances and by sharp observation in the quick-change carbon arc lamp.

The product is color, light, but what is light and where does it come from? We have just found free Rx sustaining the air and when this Rx meets the incandescent body it is thrown back with light velocity of 186,000 miles per second.

Right here is the place and now the time for the new reader to be sure that he has secured a concept picture of the wonderfully mysterious and wonderfully blessed air that is our very life and so essential that we are so marvelously made that the physical mechanism for our using it is made automatic; water, food are absolute essentials but we have to use our wits to secure them. I may surprise most readers by saying that I prove elsewhere that sound is more wonderful and more difficult to scientifically comprehend than the blessed light. And I must still enhance the importance of the air by affirming that the air maintains our nervous force. Therefore, just behold that gallon of molecules separated throughout that 800 cubic feet, and held in their places by countless millions of Rx flying back and forth between the molecules by the energy of repulsion. This velocity of 186,000 miles per second is bewilderingly sublime, but for the day time it is proven positively true.

The cohesion of an inch-square steel bar sustaining a

64,000-pound weight and the velocity of light are the two most startling, baffling and sublime phenomena of Nature.

The more one considers these facts and their daily application the more will be the conviction of their beauty, utility and truth. In a dark room the Rx is sustaining the air with a velocity of from 75,000, perhaps, to 125,000 miles per second; on lighting a match only a few Rx meet the incandescent blaze and crater of the match and are thrown back with light velocity and objects in the room are only dimly revealed; turn on the electric light and the quantity can be vastly increased, but the reason why daylight cannot be duplicated is because the sun puts all the atmospheric Rx into light velocity.

That the reader may be most pleasurably convinced that this tremendous velocity is not scientific guess work I will explain how it is proven.

When the earth is nearest the planet Jupiter the astronomers watch a moon go behind the planet and it is gone thirty-six (36) minutes. Six months later, when the earth is on the opposite side of the sun and farthest from Jupiter, they watch the same moon, and lo! it is gone fifty-two (52) minutes—sixteen minutes longer. Where do the sixteen minutes come in? The light had to cross the earth's orbit, 186,000,000 miles, or twice the distance to the sun, hence light must travel at the rate of 186,000 miles per second to cross the 186,000,000 miles of space in sixteen and a half minutes. Instead of this velocity being too large, I am of the opinion that it is nearer 190,000, because this measurement has one reflection and light loses some velocity by reflection from matter, with the possible exception from phosphorus and radium.

LIGHT IS COLOR AND COLOR IS LIGHT

That color is light and light is color, is virtually true. There is no light without color, according to the principle of what color is, and colorless is nevertheless color. They are perfect synonyms, as will be conceded from the explanations.

Color is the index of the velocity of light. White light is the greatest and dull black the lowest velocity for the human eye. The last phrase is essential, because the light for the owl and the mole are lower velocities. It requires the velocities given to drive Rx through the cornea of the human eye, which divinely accounts for the sublime velocity of light.

This sublime velocity is in harmony with all the divine laws of Nature. For consider how minute a Rx atom must be and to have any effective momentum it must have some such tremendous velocity.

It is this momentum of Rx that produces the various colors, while the present explanation of color is full of unscientific requirements. For example, the present "theory" has only one velocity for all light and holds that there are over thirty-five trillion waves to the second for red and thirty trillions for violet light. How utterly inconceivable that the eye can perceive the difference of trillions in a second. Difficult as it is, see how pleasurably reasonable to recognize red with a velocity of 180,000 miles per second and violet 155,000 miles. There is 25,000 miles' difference in velocity and the eye may reasonably be supposed to recognize the two momenta. But I will spare the reader the headaches of hypotheses necessary to arrive at the "theoretical" production of those "trillions of waves" and indicate pleasure in being thankful that they are only "theoretical."

The discovery that light travels slower in glass and water than in space is what overthrew Newton's theory, which was practically the true explanation I am giving, and established the present "wave theory" about ninety years ago, after Newton's had been in use 125 years. Now the prism proves this discovery, fact of light, and confirms the explanation I am giving. For sunlight passed through a prism gradually reduces the velocities from red to violet. The light that passes through the thinnest part of the prism, checking the velocity least, produces the red, and that passing through the thickest (and many times thicker) checks the velocity to violet, and the other five colors are between.

The present theory "supposes" there is a bundle of seven colors in every beam of light, and just the seven if the beam is no larger than a hair or, as in some prisms, three inches broad, and that the prism is capable of sifting them so as to send all the red to the bottom and all the violet to the top of the spectrum. Or that a piece of red glass can absorb six colors and reflect and transmit the red only, which seems as abundant as the whole beam of light, while the truth is that the red glass checks all the light to red velocity, hence there is no loss of light but change in color.

With this explanation it is easy to understand the cause of the color of object. Take a green orange, it is Rx holding the molecules of the orange together with a loose tension, hence when white light is used the velocity, as it is reflected, is checked to the velocity of green light. When the orange becomes more mature the tension of Rx is stronger and it checks the velocity less or to that of yellow, which is logical and accurately scientific. And it is well known that all objects must be seen with white light to perceive their true color.

I have discovered over eight new laws of color and will take room here to give the Law of the Color of Objects:

The colors of objects are due, first, to the velocity of Rx, second, to the affinity-tension of Rx in the molecules of the objects and modified in the case of delicate colors to the angle of reflection.

The last clause is very necessary because so common and verified in changeable and water-colored silks, but most wonderful and remarkable is the true cause of the gorgeous rainbow, and positively not refraction as now given in school texts.

I am trying to be a little more than fair with the reader with my promise not to use terms he cannot understand without consulting my larger work, for it would be too difficult to condense 800 pages into 100. It seems that all this is necessary, and some more to follow, to readily prove that we do see space. For after knowing all I know about physics and light in this particular as investigator for thirty-five years I only recently discovered and realize that I do really see space, and there are other new things that have come to me since designing this book, hence this is a confession that I do not profess to know it all, but enough to know how little I know of what there is to know.

PHYSICAL AND PHYSIOLOGICAL LIGHT

Accurately, light is both physically and physiologically vision, and vision is light. And since there is vision there is both physical and physiological light. In a lighted room without eyes there is the physical thing light, but no physiological light, while there will be when eyes enter the room. Now with eyes in a dark room there is no light of any kind, although the physio-

logical conditions are present, while there can be light without the physical, which may be proven by striking the head a sharp blow, but the light will be in the head and not out in the room.

This is not conjuring with words or a play with phrases but deeply true and scientific, for it proves and demonstrates that light, color, vision are sensations, metaphysical things, common, familiar and practical as they are.

We have been exploring with a wonderful, beautiful, beneficent mystery and have been as far as Jupiter and his moons and the central source, the sun, which we have been supposing supplies us with this mystery fresh every eight minutes, and we have seemed to have beheld him in his regal and far distant realm or capital, the stars, but a little farther exploration brings us nearer home, the human eye. And with this mystery seemingly and this eye we have, at least partially, made these explorations.

The eye is a lens with a special, wonderful spherical moving picture screen, the retina, covered with a most refinedly delicate mantle of velvet cilia, connected wondrously to a more wondrous mind-mechanism, to a more mysterious and higher reality.

Now we have found countless millions of Rx flashing 50,000 to 186,000 miles a second between the molecules of the air and all objects in the air, to and fro everywhere. And radiating in circles from everywherepoints they must proceed to nearly everywherepoints. Therefore since this lens of the eye is one of these everywherepoints it receives its share of this ubiquitous and bounteous Rx. And when it reaches the eye with the higher velocities this lens automatically directs each Rx and line of Rx to their special position on this

mysterious retina screen so that there is no mixing nor confusion, not one of them gets out of place and these Rx each strike this screen with the velocity with which they were reflected before they reached the lens, and right here is where my concrete and understandable explanation ends. The reader has the new material facts and may be able to explain the final mystery of light and vision better than I could.

But right here in the neighborhood of this retina-screen, or a little farther back, is the sensation we have learned to call light, color, sight, vision. Here is the seer that determines that the object from which the Rx was last reflected is a mountain, a fountain, a beautiful flower or face, for it discloses just two things, the color and the form. Are not all these things wonderful, beautiful and sublime?

If some remark that the subject of this chapter is "Seeing Space," I must reply that, if most readers are not with Professor Einstein, who declared he could have no conception of space, they are all somewhat skeptical of my ability to concretely prove my promise. Hence this condensed treatment of light, sight and the anatomy of the eye, and I have enough rudiments of psychology to give me confidence to believe that, allowing for all the irritations, in the end the reader will have been so persuaded that he will not remember me less kindly.

PERSPECTIVE

This principle of perspective, of comprehending distance, has been one of the most baffling in optics, although it is now scientifically and quite satisfactorily explained by the principle of angles. I knew a brilliant lawyer who was so perplexed over this that he actually

convinced himself that the eye projected something that grasped and returned the object subjectively to the eye. The angles mark the relative positions but are not the essential cause for distance, as will presently be pointed out.

Some may be surprised that light reveals only form and color for we do receive a vast amount of information from each object we view critically, but all this information is due to our accumulated knowledge acquired from previous information, from study of form and color elsewhere, or in the like things. For we always say, that looks like so and so, is genuine, or a fine imitation. Or take a human face, the vast information it reveals is because of our accumulated information derived from the relationships and products of form and color, for the eye records only these two things from which that "mysterious interpreter" secures the remainder.

We, therefore, now know how the retina picture is physically produced on the mysterious information screen, for from this sentinel the metaphysical monarch, the mind, is informed of the external world, and by and from which he secures the opulence and force of his imperial kingdom. But the mind must go to school and must learn from experience how, not only to use but to interpret this upside-down picture. (There is a large amount of detail connected with the retina which I cannot enter upon here, but this chapter will no doubt stimulate a great many to look up the anatomy and physiology of the eye and deepen the impressions received here.)

We have arrived at the place where psychology begins, and the problems in this branch of knowledge are many and most intricate. For there are no

measures, crucibles, acids or tangible apparatus in the laboratory of psychology.

Some facts of psychology, however, are very essential here, for we all believe we know a great deal about the knowledge and the reality of things from this retina picture that are not "so." And one thing perhaps, the majority will never be truly convinced is not true, is that even distance is an interior, local, personal sensation and not outside of us.

I will give two cases in illustration: One of a boy born with a cataract that was operated on at the age of thirteen by a noted surgeon (whose name I withhold because he did not give the boy's name with his own, for the boy should be noted as well). When sight was received everything seemed flat and he could not perceive distance. He was surprised in many ways; that pictures did not feel like the things which they represented to sight; that things which tasted agreeable to him were not always pleasant to look upon, and it was only gradually that he became able to comprehend distances naturally.

The other case is that of Caspar Hausar of Nuremberg. After being released from a long confinement in a dungeon with only one small window he could see nothing as a single distinct object; all things were just one even mottled picture of some colors and no forms. He declared when first released that he could see only a window shutter in front of his eyes, on which various colors were flitting about. And the boy, thirteen when he finally learned to distinguish the distance of objects on Epsom Downs, called it a new kind of seeing.

Therefore we understand that distance, which we seem to actually comprehend and possess outside and beyond us as surely as a thing in our hands, is only a

panorama spread on the retina which our mind or soul beholds, comprehends and projects as the actual things which are there represented. It is like the panorama of the Battle of Gettysburg, shown during the Chicago World's Fair. You entered the round building through a dark passageway and reaching the center beheld the battle and field in every direction, the scenes of which were painted connectedly on the circular walls of the building. It was realistic but a studied inspection for that purpose would prove to this same mind that it is being deceived, which is some evidence, as is claimed, that the mind really projects itself beyond its physical habitation.

The essential cause of this perspective or seeing distance is not angles but the quantity and momenta of Rx. All objects in daylight are reflecting practically the same quantity of Rx, which is evidenced by the uniform action of the atmosphere. But the greatest quantity of Rx enters the eye from the nearest objects and these produce the greatest momentum. By far the largest quantity reflected from all objects are intercepted and concerned in the maintenance of the air, and the only Rx from an object at a distance that reach the eye are those that get through the spaces between the molecules of the air. This is why I so emphasized the construction of the air by the illustration of the 800 cubic feet and gallon of liquid air. This principle is illustrated clearly by the watchmaker, who not only uses a magnifying glass, but brings the small object as near as possible to his eye, just to reduce the number of molecules between the small object and the eye.

The momenta, the impact of a greater number of Rx striking the retina should be accurately considered and conceived, for the closer the object the more rapidly do

Rx fall upon the same spot on the retina and this physical condition must have some corresponding effect to that we note from similar common events, while there may be also some deeper metaphysical effect from this quantity of Rx, which, if accepted, more positively confirms the explanation.

To more certainly but to more accurately demonstrate the proposition of this chapter I must give still more facts and especially concerning the pictures on the retina screen. There is a constant light sensation and, as I shall prove, there are pictures on the retina of which we are not aware. And this is one of the most scientific factors pertaining to the subject. I will now prove this by demonstrations that every one can confirm. On a lighted street car at night when it is dark on the outside the whole interior of the car is seen when one looks out of the window. Coming suddenly into a brilliantly lighted section all the interior disappears. It, however, is still there in the eye but the stronger, bolder pictures from without make one unconscious of it.

It is still better illustrated by a car passing through a dark tunnel. As it enters the interior suddenly appears, and plunging out into daylight it as suddenly vanishes. All through the day while looking out of the window these interior pictures are present, though usually unobserved. Proven also by a lamp or incandescent light which is so strong that however bright the day the lamp will be seen outside the reflecting glass or window and just as far away.

As already granted the present explanation and theory for distance is the principle of perspective by angles; which I contend is secondary to this new principle, namely, this quantity of Rx received from objects

at varying distance. I will give this conclusive illustration that sustains my position: I was looking out of a window at a passing freight train on the Lake Michigan front, and I saw lights through the cars for half a mile out in the lake, as it was night, and turning around I found they were the lights along Forty-third Street. Now their light was reflected from the window two feet away and there were no angles or objects to produce the perspective, hence it was the quantity of the Rx from these lights that placed them out over the lake, for the room was well lighted but it was very dark outside. This can readily be tested with a mirror any night. The moon, without angles, will seem far away, while the Rx come the short distance from the mirror in the hand but their very limited quantity produces the effect of distance.

We now have all the facts and the real factors that result in vision. And we can see that the conception, perception and consciousness of distance, perspective, is due more to the diminishing quantity of Rx received as distance increases, which is emphasized by the last illustration of unrecognized pictures. And now we See Space, for

LUMINOSITY IS SPACE

The light, the luminosity we call day, is space, for the molecules of the air are reflecting just the same, and just as truly as objects, and they enter the eye of necessity just as surely as the Rx from object and they must produce the sensation we name light and they represent space instead of material objects in space.

For in the external air the molecules are constantly moving in quantities, largely retaining their strata and column relationship, hence when a Rx reaches the eye

from any portion of space, the space where the molecule was is vacant, void, and that is just what space is, mere extension.

Hence luminosity is space.

Or, to state it scientifically, which is that of experimental fact, luminosity is the visual sensation that represents space just as the same sensation produced by the regular and geometrical arrivals of the same agent Rx, represents form and color which constitute an objective thing. Space is a uniform color, usually white, while objects alone have varying color, which mainly determines the form also.

The reader can now understand all of the results of the experiments. For light is sensation and optical sensation is light. This was proven by the first experiment and emphasized by the others.

Luminosity is the identical principle illustrated by the car window. But it is so strong and completely spread over the whole retina and so absolutely continuous, that space is a bounteous, constant pleasurable, objective sensation, that we enjoy with all too little appreciation and gratitude, until we see a string and dog made eyes for some unfortunate.

I have received so much pleasure from this latest discovery that Luminosity is Space, that Luminosity is the Reality of the Day, that Luminosity is the Cheer of a bright day in June, that Luminosity is the compelling Air of every flowery picture, the Symphony of Vision: have received so much and believing many readers will be alike inspired I must recite the scene of the inspiration of this chapter, "Seeing Space."

I had decided to reply to Einstein and was planning for this book that I had before contemplated. I had commenced my manuscript when I received a telephone

message from Miss C. Louise Lewis, saying that her father, Charles T. Lewis, M.D., who is 83 years of age and has long been an eminent and honored physician in Chicago, still living in the home that escaped the great conflagration of 1871, and an investigator of physics, the key to our meeting, desired me to take luncheon with him, and for some scientific discussion. Now the chief topic was Luminosity, for he had gone back as far as he could in antiquity to secure definitions and explanations, and had become conversant with Leucippus and Democritus. Doctor Lewis was most deeply concerned to realize just what luminosity is, for which he could find no answer, and in my attempt to explain, the explanation that I have given of the air dawned upon me, that this light sensation came from the bombarded molecules of the atmosphere and the chapter "Seeing Space" was born, with gratitude to Dr. Charles T. Lewis.

This luminosity is usually considered as white light, but such is not the case at all times. And the following illustration will help to confirm the declaration that light and color are synonymous. For the air is atomic reflection and all colors appear. The real color of the molecules of the air viewed with white light, necessary to determine the real color of all objects, is blue. This is proven by the prevailing color of the sky which is blue throughout the earth.

The sky is blue luminosity and in like manner represents space. For the blue canopy is not a fixed and solid canvas of blue at a definite distance, but Rx with the velocity of blue coming from molecules at all distances and as high as the atmosphere extends, and this one color prevailing, their multitude gives the appearance of a continuous canopy of blue. But it is of other

shades and colors, and all colors in the mornings and evenings which are most gorgeous and resplendent in colors in various parts of the earth.

The present explanation of "Why is the sky blue?" was given within the past few days, among "Scientific Answers" in the daily press. It was stated that the blueness of the sky is due to dust particles in the air, but the uniform blueness of the sky throughout the earth makes this completely untenable. The sky is bluest after a rain when all the dust is washed from the air. This "dust" explanation of the blue sky illustrates our careless reasoning. It has lived only on the "authority" of some noted person. Let no one quote me as authority but hold the facts for evidence.

Often the air is seen in watery waves on the plains and prairies. These prove the stratification of the air definitely, for these waves could not be produced were the molecules indiscriminately distributed. And it also proves that they are virtually stationary as I attempted to show in the beginning of the chapter, i. e., that they do not bombard one another but are maintained in relative positions by repellent Rx.

The rainbow is not due to refraction of Rx in drops of rain, but to the principle of reflection identical with the sky. It is from spherical drops of rain, requiring direct sun light, and by virtue of the symmetrical angles all the colors are produced. Distance is not required but definite angles always prevail. It may be seen in a fountain spray, and distant in the cloud, and quantity of drops modify its spectacular grandeur. That the rainbow is due to reflection can readily be accepted by the reader from the facts I have here adduced, although perhaps understanding the refraction explanation now prevailing, which is sound in principle, but two condi-

tions make it untenable, while there are no hitches whatever, but beautiful harmony in the reflection explanation. It is graphically and mathematically demonstrated in my other book.

The reasons green and not blue prevails in lightning flashes are the quantity of water and the fact that the flash as a whole is not all definite white light.

The explanation of the fourth experiment, a light at night, is found right here: The Rx coming from the distant light are reflected from the eyelashes and, owing to the darkness, their delicate colors are recognized. They are always there but can be noted only under these conditions. Reflection affects all color. The angles of reflection on the eyelashes conclusively prove the rainbow principle of reflection.

The gorgeous aurora has more confirmations for all the new things in this chapter than any other single phenomenon. Its streamers, stratification, and spectacular display of colors are all in perfect harmony with all the principles brought forth in the proof that luminosity is the vision of Space. The fundamental principle is reflection, and the explanation is similar to that for the fourth experiment, but the angles of reflection are at the molecules in the air, while the rainbow is from the drops of water.

We cannot see things without physical light. The reason the aeronaut and flyingman look out into blackness of darkness and miss the terrestrial luminosity is because the atmosphere has its limit, and one-half of it is within three and one-half miles of the earth. Luminosity, therefore, diminishes as they ascend into the higher regions. They experience the frigidity of the arctic regions because of the great lack of that essential element Rx, for while there are so many less molecules

with cargoes of Rx aboard, there is a far greater loss in the quantity of bombarding Rx, for the quantity of molecules is what trap Rx and hold it longer near the earth to secure more of its wonderful blessing; exactly on the principle of hotbeds for sprouting seeds in spring.

Luminosity is so mysteriously wonderful that it seems most fitting that Aristotle should call it the "divine fire of the pellucid," and that Descartes should call it "his hypothetical Ether, the luminiferous," and that science should perpetuate the name.

Besides seeing objects in the distance we see something of the real nature of "distance" all the way to the object, and it is now this luminosity of space. A light at a distance on a dark night seems to blaze only a small hole in the darkness. In a lighted room this luminousness is still present, yet in the brightest light it lacks the brilliancy of the luminosity of the day.

While the objectivity and reality of objects and distances in dreams seem conclusive proof that they are wholly physiological and metaphysical, I presume we cannot convince ourselves that we do not somehow comprehend and possess outside of our mind the distances and the objects therein. But we locate distance by sound as well as sight, which we positively know must be by experiences as with vision. Our echoes are our voices but they come from a distance after our words are gone, and result alike from the diminishing quantity of Rx.

That the results of vision, sight, the pictures on the retina-screen, are only images seen by the greater wonder mind, and by it projected without and beyond itself is true and has so been confirmed by nearly all the investigators from Alhazen, the Arabian astron-

omer, down to modern times, Molyneaux, Berkeley, Schopenhauer, Cook, to the writer of today. But the developments from the investigations on "Seeing Space" and the discovery that luminosity is space provide new factors by which to clarify the comprehension of the subject.

But I must repeat that the acceptance of the truth, the fact of distance being a local concept of the mind in the brain, cannot remove the reality of the conviction that the kaleidoscopic views of a great city, the bewitching landscapes, the sublime grandeur of mountain scenes and the distances of sun and star illumined space are comprehended and possessed by our own projected capacity, and are not just photographs in the more wondrous eye.

LAW OF VISION

Light that brings the images of near or distant objects must escape the intervening molecules in the air, hence must come in the openings between the molecules. Or just as exactly, must come through temporary holes in the air extending from the objects.

Therefore these temporary holes in the air decrease with distance, the number of molecules in the air and the movements of the molecules. I have elsewhere illustrated all of these by the watchmaker,. not only using a magnifier, but bringing the small object close to his eye to reduce the number of intervening molecules. Hence my highly prized discovery is:

The divine creative design in the incomprehensible velocity of light of 186,000 miles per second was for the purpose of distinct and distant vision in an atmosphere divinely essential for animals' existence.

Sound travels at a snail's speed of 1,120 feet a second

compared to this of light whose 900,000 times greater velocity is what propagates this great rate of 1,120 feet per second.

These temporary holes in the air are stopped by glass and water, but Rx repels light from the opposite side of the glass into continuous air openings. This is verified by the fact that if there are any imperfections in the glass the vision is distorted by the light being diverted into other holes.

If one could move with the velocity of light the hazard of speeding automobiles would be eliminated. Vision in still and windy weather demonstrates the truth of the principle. Every consideration that I can bring up confirms the value of my discovery. No line of evolutionary argument can evolve these results from primordial matter. The marvels of radium and radioactivity are all the results of this tremendous reflecting speed capacity of Rx.

CHAPTER V

THE ATOM

THE LAW OF MOLECULES

IT is necessary to have the proper foundation for any structure. It is true with all common and scientific investigation. The premise is the foundation and largely governs what follows. The atom is the premise of all scientific investigation, the foundation of the whole subject of human existence. But up to modern times, only here and there in places and times has any serious attention been given to the physical aspect of human existence. Most of the knowledge and literature, the history of the past, is from and pertains to the metaphysical which, of course, is from and based upon the physical and it, of course, again has used the physical in promoting itself.

History is the progress of mankind in the rise and fall of empires and civilizations, the mainspring of which was metaphysical and progress in the physical has been only incidental. For man first wishes to physically live for the enjoyment he can get out of life and as soon as that is secured, the mere existence, the metaphysical, takes control and begins to entertain and direct the other faculties that propel and compel him into action and conquest. In my earlier work I brought in the subject of religion in a scientific book, which has been not only eschewed but proscribed, and behold! it has been the main cause of the long struggle and the unenviable record of history just because of a false premise and foundation. The foundation was lost sight of and only here in modern times has it been found

and accepted, and lo! the physical has made the greatest progress of all times. This basis is the Golden Rule.

But I must be more specific, I have not brought ethics even into this work, but I brought a religious concept into the discussion only to place the physical on its own basis. For the laws of the physical alone take care of the physical, which is just what I am trying to do, while the metaphysical laws when they are understood bring as perfect harmony. Therefore, this is strictly a physical treatment of matter, nature, but cannot overlook the erroneous concepts that have crept into the subject from religion.

A survey of scientific progress from the beginning reveals the fact that in small sections and among a few the progress we now enjoy in a liberal measure prevailed. For witness the names that now hold sway in our texts, Democritus, the fifth century, B. C., founder of the modern democracy; Aristotle, Archimedes, Euclid, Plato, but the list is too long and it seems to me a veritable miracle that anything from those distant periods should survive because of the false foundation assumed for religion that wrecked and interrupted human intercourse. But I must mention Copernicus and Galileo, so nearly modern, but who placed the strongest and sublimest stones in the foundation of progress ever placed by men. When the truths of nature are found progress is easy and inspiring.

This introduction must seem to some uncalled for, irrelevant and out of place. I am not writing a mere school text, but wish to throw around the new facts a historical setting that will make them more readily remembered. But I have confidence to believe that all readers, and scientists in particular, will give their approval when they have read what follows on the

"modern atom." For Leucippus, the discoverer of the atomic structure of matter, had a more reasonable and a more nearly true concept of the atom than the one that has worked its way into our school texts and public press. And I am impelled to this course by my own experience, for when this "electron theory of the atom" appeared a few years ago I said, "Oh, that is so far from the truth, so completely hypothetical, so far out of bounds of common reasoning from observed facts that it will soon die." And an encyclopedia expressed the same sentiment about that time, when lo! in a recent edition it gives an elaborate explanation of this very atom.

Therefore, some one must present the facts and if a better atom cannot be conceived we must go back to Leucippus 500 B. C. and Democritus, who perfected the former's concept. This is positively necessary to keep the wonderful and wonderfully accurate experiments of present physicists from being total losses. The equipment was never so elaborate and facilities and means so abundant. But from misinterpretation they will go by default into the discard and future experimenters get credit for what has already been discovered.

The cause, undoubtedly, for the failure of my prediction of its early demise is largely due to transcribers who write for the public press, and, as may be seen, it certainly furnishes a fertile field for the imagination and thus it has become so popular that public speakers and ministers employ it lavishly in illustration. I am so zealous for the truth in physics that I am pleased to put my understanding of this modern hypothetical invention in public print so that I may be given a better conception, if I am in error, of the atom that still eludes the scrutiny of the microscope.

The situation is so important and serious that in order to make easily clear every feature of the problem, I must review and formulate some common axiomatic understandings.

SOME PHYSICAL AXIOMS

Law of Contact

There is no action of Energy nor effect of Force without atomic or mass *contact.*

I. Whatever occupies space is matter.

II. Energy is the prime cause of all physical phenomena.

III. All Force is only the product of Energy.

IV. No effect of energy or force is possible without the *contact* of matter.

V. Energy is the capacity of the atom to cohere or repel.

VI. Cohesive Force is the cohesion of all mass.

VII. Repellent Force is the repulsion of Rx in all gases.

VIII. Light, heat, electric and magnetic repulsion is that of Rx.

IX. Momentum Force is solely matter in motion.

These are fundamental, known facts and not debatable in the explanations in this book. They are the conclusions of experience, the consensus of all scientific investigation and established meaning of words. They are given to facilitate and abbreviate explanations as were the Propositions of Chapter II.

The same name should not be given to different concrete things, and since energy and force have been used all too much interchangeably, they must be accurately defined here to conform to these axioms, and they must

be so understood in the explanations and their use herein. I use *must* only as the key to my interpretation of the facts.

Energy is the capacity of matter, or anything, to act and the result of every act is force and is not and can not become energy. Therefore force cannot increase itself. If any more force or motion appears to result from any force, it must be due to the action of newly released energy. Energy is the capacity of atoms to cohere or cling to each other, and when they do cohere the action is known as cohesion. Repulsion energy is that of Rx and these are the two and only energies in my explanations. Hence in these axioms and in my books energy is understood to be the capacity to act under the proper conditions, and force as the name of the resultant action. Since matter is indestructible so is energy, and since force is being constantly created it is also being destroyed. This is true of all known energy and all known forces. It is because of the failure to apply axiom IV that the modern atom must now be investigated, for without contact it is action at a distance which Newton declared was "unthinkable" and I say impossible.

THE "ELECTRON-ATOM"

This atom is now defined in text-books, and by scientists, as a positive charge of electricity as a center or nucleus, around which are revolving hundreds of "electrons" in perpetual orbits, the kind of atom being determined by the number of orbits, and the miniature, invisible system is likened to the orbits of the solar system.

There is the invisible atom that has so completely discredited me as a prophet, for instead of learning of

its demise I must peruse its victorious conquest in the encyclopedia. I know I am not vindictive, but that impels me to espouse the cause of Leucippus against the impossible intruder. This atom has already done harm and it will continue to wreck expensive (in cash and labor) important experiments until it is disarmed.

My first draft of the arguments in the usual literary form seemed to leave one lost as in a forest, an abundance of trees, but where were we? This is relieved by the categorical arrangement of real categorical arguments, and I believe when carefully studied no one will charge me with even exaggeration or vindictiveness.

1. There are three unknown, invisible, hypothetical things, charge, electricity and electrons, given to define another invisible, hypothetical thing, the atom.

2. It violates the axiomatic law of *contact* twice, as its orbits cannot touch, nor atoms touch each other. This one alone destroys it utterly.

3. Electricity is admitted as an unknown force, yet two electricities are implied. Unscientific and untenable.

4. "Charges" are things unknown, experimentally varying and cannot be assumed for a thing known to be constant.

5. The "electron" is unknown, unseen, undefined, while the supposed "electron" in experiment is as elusive as the atom.

6. The centrifugal motion, so obvious and essential in the definition, is unaccounted for. And it cannot be accounted for, because contact is positively essential.

7. The centripetal force is as essential, and requires some additional force and material agent, which are not mentioned or implied.

8. No provision is made to prevent collisions in the "electron orbits" and the limited space makes collisions inevitable and continuous.

9. If the orbits are in one plane they would be excessively large.

10. If the orbits are in one plane all atoms would be flat and be discs, limited in piling and structure in mass.

11. The orbits exclude the possibility of strengthening one another as they cannot touch.

12. If the orbits are in separate planes they would intercept unless varying in diameter.

13. Virtue, force, capacity, everywhere in nature comes from magnitude, while reduction in size is here used.

14. The virtue, power of the "electron," is placed in its motion, while motion produces only momentum, and motion requires magnitude for effective momentum.

15. The compressibility of mass proves that the orbital spaces, if there were any, would be crushed.

16. The "kinetic, molecular theory of heat" although it is only a theory and as contradictory) calls for less motion; why, then, are not atoms always hot?

17. The dilemma of needed space is attempted to be accounted for in the novel way of making the "electrons" so infinitesimally small that their orbital space, measured by the "electrons," is comparable to measuring the distance of the sun by the size of the earth. This overlooks three things; first, that power is lost in reduction of size, and second, that the comparison of spaces is not altered by the size of the measures, and third, by using two measuring rods. I had adduced many more but will rest the whole case on

18. Axiom IV, the law of *contact* alone excludes it from being the possible atom of nature.

These are the indictments I bring against this "Modern Atom," because it would not fulfill my prophecy and die a natural death. Any one of the eighteen counts is sufficient to exclude, banish it from any scientific recognition. Not withstanding my prophecy, I was shocked myself when I had written out nearly thirty counts, and not even to seem vindictive I stopped with eighteen.

As a preliminary to the discussion of these indictments, I will make a restatement of an axiom or law.

Circular motion requires at least two actors for its continuance.

This is a consequence of Newton's First Law of Motion, viz.: A body in motion continues in a straight line until some impressed force changes its direction. Since circular motion is a continuous change of direction, the axiom is established.

I have shown that force must be a thing, an entity; there must be a second actor. In whirling a ball held by a string the ball is diverted from a straight line by the string, which is a continuous second actor. It is inaccurate to say that the sun holds the earth in its orbit, because they do not touch which would be action at a distance, would violate the law of contact and Axiom IX. Rx holds the earth in its orbit (shown and illustrated in the "new Physical-science" but the sun supplies a constant stream of Rx and each affects the earth when they come in contact. But the "electron-atom" builders seem to have overlooked these laws and require "electrons" to go round and round at great speed by their own electronic capacity, which a human being cannot do without using a second actor. Hence, had

they realized this, they would have had to supply a string attached to the "electron" and center of "positive-electricity"; or have the imaginary "center" supplying a stream of actors as does the sun, in order to keep the "electron" from flying off on a tangent. It might have been more difficult to find the "string" or supply of "actors." I will not increase their dilemma by requiring an explanation of how the "electron" can maintain momentum under these conditions. Hence, by Newton's established Law, I have shown the electron-atom to be an impossibility, without using one of the eighteen indictments which I had laboriously formulated.

I will show my regard for present science by saying that the professors will be shocked and that not one will take issue with me, but rather thank me for calling their attention to the intruder whose credentials they accepted without investigation because some accredited name was signed. They simply have not investigated and when they read in some book or newspaper article, as I have done: "They have demonstrated the 'electron atom' and what was supposed to be a unit, a single thing, turns out that a hydrogen atom is made up of 1,000 electrons revolving around a center of positive electricity;" they just wondered for a moment and then the word "demonstrated" lulled them into making no protest.

Now the "luminiferous ether" is just as great a delusion and if I can succeed in banishing them, and the "kinetic-molecular-heat theory" from our text book, I will secure the thanks of all future students for relieving them of straining their natural reasoning before they could be promoted in their grades. For to believe atoms in iron or any mass do not touch reason gives way

(because of the theory) to "it must be so or we could not have heat." "The molecules must be flying around like mad," said Miss Ida May Yates, my niece, who was attending an accredited college.

Every one will wonder over the cause of this sad situation and it should be known, understood and *Self-Applied* for nearly all readers have suffered from this cause: *The Misunderstanding* and *Use* of Force. Hence I cannot repeat too often on this point. Force is action always and everywhere, but is always the result of energy starting the motion. One cannot move a finger or think without these two. The energy moves the atoms that act on the muscles and the finger moves. Now this energy act is cohesion. It is the same energy that makes sugar or salt a mass when wet as when one moves a finger. Energy is like shaking hands, when the atoms meet they grasp but hold on, and to hold hands one must continue to use energy. Energy throws the ball or hurls the bullet, but force keeps them going and accomplishes whatever results follow from each. I will formulate an axiom in order to straighten out the greatest barrier to scientific progress.

Each force is merely the energy action of some actor.

Force cannot be considered apart from matter.

This is not axiomatic but is an axiom, a self-evident truth, for energy and force whatever they are must be in or associated with known matter or other tangible matter occupying space, else they are void, nothing.

This was just as true before I discovered Rx, which, of course, greatly simplifies the understanding by furnishing a tangible concept for Repulsion, for cohesion has always been known, but up to this very hour has been considered something outside and differing from

matter. It is essential to say that in my larger work I quote authority for such strong statements as the last.

This showing of the "Modern Atom" surely gives license for my introductory remarks, for I knew what was coming.

NECESSARY PARENTHESIS

Prof. R. K. Duncan's "The New Knowledge" was issued in 1907, which treats of the "ion," "corpuscle," "electron atom," "radium," "uranium," "uranium X," "thorium," "thorium X," "helium," "emanations," "alpha, beta, gamma, rays," "Lenard, Becquerel, Rœntgen X-Rays," Mendeleef's "Tables." Since this, and by so many other sources, "The New Knowledge" has been scattered abroad, there will be a large per cent of readers so posted that they may believe I am not posted in these matters and hence get less out of my book.

Therefore I must state that I had read and criticized his book (and the science editor of the *Chicago Tribune* endorsed my criticism), besides looking elsewhere for the very latest developments. I accept and hail all new knowledge, but less than half of this "electron-atom" is real and new knowledge, the other is misunderstanding of wonderful, wonderful experiments and 95 per cent of the explanations are not true. It is out of the question and useless for me to take up the "New Knowledge" in this manner in this book. But as a contrast and revealing the gain in my new physics, I present to the reader a short summary and comparison. It is proper for me to say that Professor Duncan is here merely a transcriber and did not originate "The New Knowledge," and is only responsible for being misled into the swamps of its hypotheses.

Professor Duncan starts out with, "1 Matter, 2 Ether, 3 Energy," while I use only Matter. Hence my contention against the Ether, and the misconception and use of Energy and Force are here proven, for they are conceived as something apart from matter and in fact he calls them "non-matter," and yet nearly fulfilling his definition of matter. This results from a misconception, or no concept of Force, which is so essential.

Hence I require one-third of his foundation, and besides I define Energy and Force and give them "local and material habitation and a name." I know and define what Energy and Force are, prove and show where to find them, while he does not even attempt to do so.

While we both accept the atomic structure of matter, he uses this "Modern Atom" of a multitude of inconceivable "orbits," while my atom is a unity and of sufficient size to possess Energy, a capacity to produce Force.

Professor Duncan defines matter thus:

> "Science is naive; she takes things as they come, and rests content with some such practical definition as will differentiate matter from all other forms of non-matter. This may be done, strictly provisionally in this place, by defining matter as that which occupies space and possesses weight."

The first part of this two-part definition is the same as mine, namely, that it occupies space, but what an impassable gulf he opens between us by adding "possesses weight." It is drastic enough for me to ask that my matter possess Energy, capacity to act when acted upon. But to ask an atom to possess weight. This really is too unscientific. Let us take one of his "weight atoms" out into empty space, a million miles from other matter or force of any kind. It has his "weight," but which way

is the poor thing to fall? How does it know direction? For man with all his intelligence cannot determine direction without a guide.

But I will now let the reader into a profound secret, why the "possesses weight" was included. It has already been written above. It was to take care of "The Ether" because if the ether were given weight it would offer resistance to matter and what havoc it would have made with the earth's atmosphere!

"ENERGY"

Observe that this is not the energy of my book. After a paragraph disquisition on rest and motion Duncan sums up "energy" as follows:

"This cause or this power to change the state of motion of a body is energy. . . . . Just as matter may exist in so many forms, so may energy, a list of the forms of which we append: 1, Kinetic Energy; 2, Gravitation Energy; 3, Heat; 4, Energy of Elasticity; 5, Cohesion Energy; 6, Chemical Energy; 7, Electrical Energy; 8, Magnetic Energy; 9, Radiant Energy. The list comprises 'forms' of energy and not 'different' energies for the reason that they are one and all interconvertible. Energy is protean in its nature, for it may be converted, directly or indirectly, into any other form. . . . . It is possible even that these very 'forms' may not be distinct from one another, actually, but are simply so many different varieties of motion. However that may be, energy is not only transformable but transferable."

There is the foundation of Professor Duncan's "The New Knowledge." Energy is something outside of matter, the "non-matter," undefined, unlocated, transformable, transferable, and matter in motion contains more or less energy.

Contrast this THEORY with the simple sense attested foundation of my books. ENERGY IS THE COHESIVE CAPACITY (NOT COHESION) OF ALL ATOMS AND Rx, AND THE REPELLENT CAPACITY OF Rx ATOMS OF KNOWN

TANGIBLE MATTER ENERGY IS THEIR CAPACITY AND WHEN THEY ACT, FORCE RESULTS.

Duncan's foundation and whole list are the products of these two capacities, combined and alone.

I have just made a strange discovery. I read "The New Knowledge" nine years ago, but just now looked for the word Force. It is not in the Table of Contents nor the Index. Strange, isn't it? Yet in the books my father studied the word Energy did not occur, hence Duncan merely substitutes the word Energy for Force of one hundred years ago.

To vindicate my attacks on the "Ether" and the "kinetic-molecular-theory of heat" and now my restrictions on the "electron-atom" I must make the following quotations from Duncan's book:

"A thing must be defined by its properties and the properties of the ether are for the most part negative; so negative, indeed, are they, that when one says boldly that we cannot see ether, hear it, taste it, smell it, exhaust it, weigh it or measure it, one feels timid that sane-minded people will meet these negative qualities of our ether by a decided negation of belief in its existence."

While with Rx every one of these seven things are positive. And Rx is the very force that runs the radiometer which he uses to show that the ether is visible "to the eye of the mind." And then the following on the kinetic-molecular-theory:

"Now, this motion (atomic) is continually changing, from one velocity to another, and the same kind of reasoning that led us to believe in the ether leads us to believe that a body can go faster or slower only because of some cause, and this is energy."

We both use the word ENERGY, but I place it as the capacity in the atoms of matter and Duncan places it in a something he calls non-matter and requires it to perform what I conceive as the impossible and positively miraculous. For this mere "motion" has the

legerdemain capacity of being "heat," "gravitation," "kinetic," elasticity," "cohesion," "chemical," "electrical," "magnetic," "radiant," "energy," "motion." For he also states:

"The first assumption . . . . is known as the (Newton's) 'corpuscular theory,' and was killed outright and buried years ago after a battle royal."

I now serve notice on Professor Duncan that it is very much alive for Rx has come back to expose the unrighteous taking-off of Newton's theory of Light.

The experiments noted in "The New Knowledge" are most erudite and wonderful, and I cannot criticize them in the least, but what pains and distresses me is the sad and woeful misunderstanding and misinterpretation of them. But these are unavoidable with such a false Foundation as I have above shown, with "Energy" and "Ether," and especially calling them "non-matter," while they must occupy space, the one only unassailable definition of matter, or they are void, nothing; and that is my claim that they are nothing, do not exist, and are really "non-matter."

But I was most gratified by Professor Duncan's closing chapter, in his valedictory, to discover that he is a believer in God, hence he and science will be led to see that all of God's mysteries, when they are discovered, meet man's reasoning and are beyond man's simplification or improvement, and that there are no conflicts in discovered laws. Why, then, seek to solve other mysteries by complicated means and persist in them when we see they conflict with discovered laws and experience? Oxygen is always oxygen, hydrogen, hydrogen, but combined produce water and always and only water in the same proportion. Why, then, were they not given by the Creator distinct natures and water

an unalterable nature of their combined natures? It is this nature of matter we have not been able to discover. But we have discovered that matter occupies space, is atomic and that the atoms cohere or repel. A greater mystery than even matter is the velocity of light and the greatest physical evidence of a Creator. For we can conceive matter as always existing, but we cannot conceive how under conditions light can be propagated as Rx or even "waves" at the astounding speed of 186,000 miles per second.

Therefore I will pay no more attention to this feature than what follows on the "modern atom," but this much should serve to give us our bearings in this voyage of exploring physical nature. Yet this misunderstanding has had such a far reaching effect that there are those who believe in the transmutation of matter, while perpetual motion is a more tenable proposition.

I really should take up these nineteen indictments one at a time and elaborate on their validity of disqualifying this kind of an atom. But I will rely on the reader going over them twice to nineteen times to make sure they are correctly drawn.

Practical science is so drastic in its demands of tangibility and measured quantities I cannot understand how they have sanctioned such fancied imagination; too far fetched for even the theoretical. But the facts are that some of the best and erudite scientists have not come out in support of this "dreamy" atom.

The "kinetic-molecular-theory of heat," seemed the limit of contradiction of all experience and known laws, but see how it really should be pardoned when Nos. 6 and 7 are considered. How can tangible things or any imagined force maintain such orbits within solid, rigid, cohered mass?

No. 14 ruthlessly breaks the law of *contact,* for no effect in all nature is known without *contact* of the things affected, for the unaccounted-for motion, as indicated by Nos. 6 and 7, prevent contact even were it possible for such motion to exist. Then everywhere in nature force is never visibly observed except in proportion to magnitude while this line of reasoning on this "modern atom" has caused scientists to declare there is enough energy stored in an atom, if we could get it, to blow a battleship over the Washington Monument. To counter this I must repeat the new physical axiom of Chapter III, viz.:

Every atom uses all of its maximum energy possible under every condition. Nay! It is a universal Law of Nature.

To assure the reader that I am dealing with the actual state of affairs, and also to show the elaborateness of the experiments that must have been made, I must quote from "The New Knowledge."

"If, therefore, the mass of a corpuscle equals 0.00000000034 divided by ten million, and the mass of an atom equals 0.00000000034 divided by ten thousand, it follows that the mass of the hydrogen atom is one thousand times greater than the mass of a corpuscle."

Therefore try to conceive that a hydrogen atom, that the microscope cannot discover, is made up of 1,000 corpuscles with orbital space, and a center of positive electricity!

Some may not be able to accept my physical axiom because of the recent discoveries in gases and explosives. But in every case it must be remembered that they are new atoms and combinations, and that quantity is still required. It is by the truth of this axiom that every engineering computation is made. For all those who know how the engineers test the tensile and resisting

strength of every kind and inch of material they use in their important structures, the force and truth of this axiom is at once obvious and alone ruins the "electron-atom."

This universe cannot be explained and understood without this Law of Nature holding true. Then why will any one blow up battleships with the energy an atom has concealed in its "spacious" magazine?

The gravity of the situation has caused me to use more space than I intended. I shall still subscribe to my prophecy concerning this "modern atom," merely extending the time until the scientists themselves are at leisure to write its epitaph. But scientists will ask, "How have we been so misled?" And the readers ask, "Why have we been reading 'there are nothing but electrons,' 'electrons are in constant motion,' 'everything is made of electrons'?"

I can answer all of these and it will be a good excuse for living scientists because it has largely been handed down to them in books, and they, specialists, did not take time to investigate and turned the task over to me.

I have quite answered the situation already in the treatment of Energy, Force and Motion. The "motion" notion of energy originated about 1800, and the "wave" motion of light supplanted Newton's theory about 1830. But the scientific explanation of this dilemma is a very subtile and concealed cause and due to the erudition of the scientists themselves which no one now suspects.

Mathematics is considered perhaps the most erudite of the sciences. The mathematicians took hold of the subject of "invisible forces" with which the physicist was working. They began by giving unit values to physical effects and to electrical, magnetic and gravita-

tional "supposed" causes; then, taking the "hypothetical ether" and mathematical factors, worked out schemes that were mathematically correct. Briefly, certain values can be given to all the factors in the "modern atom" and reach fairly good results, but when the actual work is to be performed by these factors they cannot meet the conditions in any particular whatsoever.

It is the same situation considered in the Einstein Relativity investigation where they try to use both physical and metaphysical factors in actual problems. The latter merely directs. For example, the body and mind are a perfect illustration: the body actually requires food and motion. The mind calculates just how both must be procured, but the body must do all the work. They are absolutely unrelated in execution.

Again, and actual, it was mathematically supposed that a beam of light consisted of seven colors. Then supposing that a red apple absorbed six colors, one can account for the red. And this has held for ninety years and yet when one gets down to the actual fact of explaining what light is, how the seven colors get into every beam, where are all the other choice colors concealed, and how the absorption of the six and reflection and transmission of the seventh, you have a dilemma on your hands like the "modern atom." It simply cannot be done. This atom is impossible. Mathematicians are all right in their place, and I am pleased to be able to be one by working out ten or more new mathematical laws. Clerk Maxwell's ponderous mathematics on the ether hold rigidly to mathematical laws, but tangible matter and forces cannot execute their evolutions without breaking all their own laws. *Besides, the Ether does not exist.*

FORTIFYING MY POSITION

As illustrating the newness of this atom and the effect its hypothetical treatment is producing on transcribers and literators, Mr. R. H. Blakesley, a subscriber to the new physics, brought to me at the last moment an article on "The Electron-Atom" over which Miss Lillian M. Brant, a new student of the new science, was greatly concerned. It is such an epitome of what I have written on the "Electron-Atom," and being so fresh I must notice its declarations. The article was illustrated by Fig. 4 for the purpose of showing that the space of an atom measured by an "electron" is greater than the space of the earth's orbit measured by the earth. By

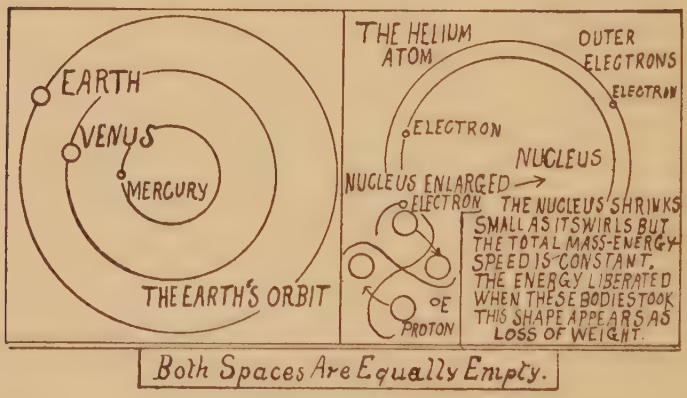

FIG. 4. "ELECTRON-ATOM" TO DATE

the courtesy of the *Chicago Tribune* I reproduce the illustration.

For lay thinkers I submit this problem: that, since it would take the earth at the rate of its motion, 18.5 miles per second, 114 days to cross its orbit, how long would it take an electron with one-billionth of the earth's velocity to cross its orbit, which is within an atom of

matter? And yet they claim the "electron" has frightful speed.

Besides, there is no virtue, physical or material effect from the motion of the earth; should it decrease to one mile or increase to 100 miles per second and remain at the same distance, we would not know it nor would it affect anything. How unscientific then to suppose any potential result from the motion of an "electron" since it cannot touch anything for that would stop its motion.

The article verifies my statement, "It has done enough harm now and will continue if not exposed." For it adds a new word that I have not met. It is new because it does not occur in Duncan's "The New Knowledge." The word is "proton," and it may be seen in the figure in its orbital motion.

Science disclaims to know what electricity is, yet read what this article says: "The atoms which compose matter are made of 'protons' and 'electrons.' These are particles of positive and negative electricity." Then read this: "An 'electron' weighs 9 times 10 to the minus 28th power in grams."

Then regarding the spaces in the figure it says, "Both spaces are equally empty." But I say if their spaces are compared that 1 with 500 cyphers following would not equal the real difference, and using their comparison "electron method" 5,000 cyphers would not do so, for listen to this: "An atom contains relatively less matter and more open space than the solar system." That surely is a "Relativity" that we have not reckoned with. But their mentality seems to have no limit to its imagination, for we read:

"The loss of mass when an atom of hydrogen enters into the helium atom is equal to a unit charge falling through a potential

of about thirty million volts. If all the hydrogen in a thimble full of water were to be converted into helium, the work released would be 200,000 kilowatt hours."

I should like to know the reader's own comment upon that. In reading the following quotation bear in mind that the munificent "space" mentioned is all contained in the boundaries of an invisible atom. And note that it is stated with all the assurance of fact as though describing the pyramids and giving dimensions, while it is solely highly colored imagination.

"Protons are the centers of little systems and electrons form their satellites. The structure of an atom is exceedingly complex, but resembles in its plan the structure of a solar system. A hydrogen atom consists of one proton, circled by a lone electron at a great distance away. All other atoms are more complicated than this. Instead of a single 'proton' many have multiple protonic systems for nuclei, for transcending any known multiple star system in intricacy. About these spinning nuclei and at truly enormous distances away, the satellite electrons revolve."

It does appear to me that no atheist could make a more desperate attempt to account for the universe without a Creator. Who can explain to me how this dozen or score of scientists conceived the notion to secure force or power by contraction and condensation against the universal experience of mankind that it is only secured by quantity. Even electricity in every department requires increased quantity. Nature impresses the universal law. The mountain is vast and sublime because it thus exceeds the molehill. The sun is supreme because of its majestic magnitude and quantity of heat. If anyone longs to serve the cause of the students of the future, budding intellect, let him join the allies against the invasion of the "electron-atom."

The failure of my "prophecy" and yet the verification of its harm were forced to my attention a day later

than the above. For as I passed Washington Square, Chicago, I heard an eloquent aged street orator discoursing to a mixed street crowd on socialism, I presume, as his main theme. But he had a chart 2½ by 3 feet headed, as I remember, Biology, Electrons, Economics, Socialism, and on it was pictured electron atoms, the earth, solar system, etc. And I heard the orator say: "The hydrogen atom, the smallest atoms, is made up of 1,845 electrons in orbits around a nucleus of electricity, like the orbits in the solar system, etc." This lecturer is not a physicist but a promoter, transcriber, and must have access to books that I have not seen for here was a vast increase in the hypothetical orbital electron.

I was startled at such an extravagant increase of the imaginary "electron atom" I had treated in my MS, that this use and propagation seemed to demand a few more words from me to express, in this case, my personal view of the facts of nature, which I have not done in the book.

How sublimely reasonable is the hard single-thing atom of Leucippus of 2500 years ago in contrast to this imaginary impossibility! Besides it violates experimental laws, all human experience and common reasoning. Too small for the powerful microscope to discover, yet the hydrogen, the smallest atom, is composed of 1,845 "electrons," smaller "things," but more exasperatingly difficult, each whirling in vast velocity in its own orbit!

O sublimely wonderful and sublimely simple Nature! What would this marvelous universe be had the imagination of man designed your now perfect laws! It is vain to speculate on the meaningless chaos that would have issued!

Each atom is a single, princely individuality with special potential capacity and character just large enough to perform its required function by the *Inviolable Law of Contact.*

What good, what virtue, what possible part could an "electron," if it existed, play in the sublime scheme of phenomena, if it could only spin in its orbit and not touch anything?

O Leucippus! Democritus! come back from thy oblivion age and teach us to think straight!

The down must hang upon the lily's cheek; the atoms of the flinty rock and the steeled-beam must touch and cling with cohesion's greatest force to hold the mountain firm and the arched-bridge that spans the mighty river's turgid flood; for *touch* is so wonderful, *contact* so essential in every realm: The flower's aromatic breath must mingle in the nasal labyrinth; the summer's sweets dissolve within the laboratory of the lips; and the attenuated air must play upon the vibrant tympanum; material Rx from earth or sky must dance upon the velvet carpet of the retina; while finger tips become the eyes for orbs that cannot see; thus only by *contact* do the elemental atoms yield up and make known their potentialities that produce the real and essence, the business and splendors of a universe and unfold the transcendently sublime panorama to reproducing mental personalities. Thus the material and the mental from the embrace of *contact* cannot be divorced.

How utterly fruitless then and unreasonable to force and picture explanation with an "electronic atom" that does not exist, revolving in concealed yet touchless, contactless orbits, while producing all this wonder and sublimity in realms where *contact* rules supreme!

It cannot be done.

ALONG THE SAME LINE

The chief design of this chapter was to establish the Law of Molecules, my latest investigation and next the presentation of the facts of the "electron atom."

I confess to a keen desire to expose this "modern atom" because of its progress, already noted, because of the harm it has already done and the loss it will occasion of experimental cost and mental labor. And also loss of credit to the faithful experimenting physicists, for in the future others would get credit which now belongs to them. I must illustrate this phase.

Prof. Henry Gwyn Jeffreys Moseley, that brilliant physicist of England, who was shot and instantly killed in the trenches of the Great War, had, at the age of twenty-seven, made remarkable discoveries that have been sadly misinterpreted because of this atom. For he made experiments that when rightly understood will demonstrate the graduated affinity between Rx and all other atoms. Another striking illustration is that of Robert Brown, also an Englishman, who in 1827, made discoveries that are known as "Brownian Movements," which were supposed to be explained several times while they are consequences of the principles given in this book: A more recent case is that of Prof. R. A. Millikan whose brilliant experiments have been so sadly misinterpreted as to be given by himself as confirmation of this "modern impossible atom." And this failure perfectly illustrates the 'e'xcuse" I have given for this sad situation, because he accepted the mathematical treatment and mathematically worked his discoveries into the "theory." For his experiments are also confirmations of the principles in my books.

Rx is the only isolated atom known.

And Rx is only alone as light or while bombarding the molecules in gases. These are essential consequences of its repellent nature. With this understanding of just what gases are the phenomena of Crookes' and all vacuum tubes are readily explainable.

Professor Millikan by an elaborate experiment supposed that he had weighed an "electron." By the present concept of the electron, were that true, light, heat and electricity would have weight which they do not and cannot have. But he may have weighed some kind of a molecule as above defined, for gases have weight.

Here is a more recent case and even a greater mistake or wrong interpretation of results. Prof. A. A. Michelson claims to have measured the diameter of the bright star Betelgeuse by an "Interferometer." He may have measured the star but not by the false principle of the "interference of light." The "principle of Interference" cannot be any better sustained than the "theory" of the "electron atom." In Preston's "Theory of Light" perhaps about one hundred pages are devoted to the hypothetical explanation of the hypothetical "principle of Interference" of hypothetical light "waves." I was obliged to use twenty pages in my work, "The Science of Physical Phenomena," to disprove it, and give the proper explanation of all the cases of the phenomena explained by the hypothesis of "interference." And here is a startling fact for students of this subject, viz., this false "principle of Interference" was used in the overthrow of Newton's "corpuscular theory of light," which was so near the truth of light that it touched it in one vital particular, while "waves" is the most remote theory possible.

The principle of the "Interferometer" is even more improbable than the problem of the "Billion Boys"

illustrated by Fig. 1, in Chapter I, for the minute "waves" of the supposed ether must interfere in a marvelous way to produce (as is also supposed) color. They are each impossibilities.

Therefore it can be seen that I cannot take up the discussion of the "Interferometer" here, as I have the "electron atom." With the principle of "Interference" the symmetry and the harmony of divine color could no more be secured than music from a thousand bands and other instruments all playing out of time.

If Professor Michelson's instrument has measured Betelgeuse, a proper name should be given to his instrument and a scientific explanation.

Professor Michelson is to make an experiment with light in connection with Professor Einstein's Theory and here is an opportunity for a prophecy, namely, that if he secures results they will confirm the principles in this book and not the "Theory" they are after. And I wish to express my pleasure in the prospect of the experiments.

But what an anomaly! Professor Michelson is to experiment on "hypothetical waves" of light in an "hypothetical ether" to see if there is a variation of the "hypothetical waves" "going and coming" to demonstrate part of Professor Einstein's "Theory of Relativity," while the latter in his book declares there is no such thing as the "hypothetical ether," hence no "waves," but nevertheless he hopes that his "Theory" may be proven by "waves."

If he experiments with light, it is Rx.*

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*PUBLISHER'S NOTE—This was written by C. S. Page in 1922. A review published in the *Chicago Tribune* of Jan. 19, 1925, commenting on the results obtained by Prof. Michelson's experiments confirm "Page's ether-denial," and we reprint it, in the beginning of this second book with extreme pleasure and satisfaction.—Atomic Research Association.

THE PAGE ATOMS

Atoms are the smallest, indivisible, natural divisions of matter, are over ninety in kinds and have only two known and provable attributes, namely, to cohere or repel, and Rx is thus far the only known kind of atom that repels its own atoms but there is a cohesive affinity between Rx and all other atoms decreasing from the strongest to the least.

Each kind of atom is a solid, single mite of divine matter.

This is the atom of this book and my larger work "The Science of Physical Phenomena." They are sense —attested and experimentally provable. Rx is the best known matter and the only atom whose weight is positively known, for the weight of every other atom is only relative to the unknown weight of the hydrogen atom, while the weight of Rx is absolute zero.

Because of the newness of Rx this repetition is advisable, for the fuller comprehension of Rx the clearer and more definite will be the understanding of all phenomena. In the history that follows it may be seen that this Rx is nearer the Leucippus atom, the original progenitor, than any since that ancient period.

HISTORY OF THE ATOMS

Leucippus, about 500 B. C., is accredited as being the father of the atom, the atomic structure of mass matter, and void or empty space in which matter could move. That matter was not a mass of thinned and hardened jelly but made up of a final indivisible, invisible hard atom. These were built up into various masses and cemented by some force. The beginning also of the "force" trouble.

It is to be regretted that so little is known of him that even several places contend for his birthplace. But a fellow Greek, Democritus, who is considered about the greatest Greek philosopher, took up the theory of Leucippus some 40 years later and left the atom in a perfect scientific conception compared to the atom with which we have just been laboring.

Democritus defines the atom as the smallest individual part into which mass could be divided, invisible, indivisible, and incompressible as it was solid, filling all the space it occupied. It was homogeneous, differing in mass only as A to N, arrangement as AN and NA and in position as A to Z, N on its side, and possibly in magnitude. Quantity was the aggregate of numbers and quality configuration and combinations. Being solid confirms the correctness of No. 16 in the list of arguments.

All phenomena are secured from the elemental atoms, therefore nothing perishes absolutely when it seems to disappear, hence the law of the indestructibility of matter, from which is derived the present law of the conservation of energy.

Democritus considered atoms eternal and uncreated (doubtless "primordial matter") and that motion was co-equal with the atom, eternal, that every motion comes from preceding motion backward forever. Undoubtedly here is the source of the quite modern theory that matter possesses energy only by being in motion.

Cohesion has always been the perplexing problem with the atomic theory and has had some attention from most of the philosophers of the past.

But as I have shown cohesion was always considered as a force apart from matter, without any material properties, not even mass or form, hence nothing more

conceivable than space. But considered as the capacity of atoms to cling to one another from contact, nothing clearer could be required.

Democritus did not limit his investigations to the physical atom but had also a psychic atom, and refined it into an explanation of the gods of mythology. The soul was not a physical atom but permeated the whole body and perhaps only specialized in the brain. We can only judge from his conclusion how he considered his atom in the human anatomy for the psychic atom perished with the dissolution of the body.

NEW LAW OF MOLECULES

The Law

Molecules, and especially in organic structures, when in a solution of their atoms, free or in molecules with a weaker cohesive tension, will form like molecules from these atoms and cohere them into the structure until it is complete, or (as in the case of some glands) throw off or store the excess molecules until the supply of atoms is exhausted.

For the professional biologist I could very briefly give the crucial arguments for its most probable accuracy if it were not for some new factors which he did not have as a guide in his microscopic explorations. He may see at once that it is in conflict with the "cell theory." Although the cell is used and generally accepted as an established fact, it is only the "cell theory," for many biologists do not accept it because of difficulties that it cannot take care of. The cell is positively there in all vegetable and animal tissue, but this law of molecules conflicts with part of what is now considered its functions.

But this book is designed for the general reader, and

although it may take some length to establish the accuracy of the law, I will use only the facts of biology that all should have for social intercourse and personal profit.

Play and pleasure in literature is where the author skilfully puts in a new dress what the reader already knows, and he will smile, laugh and say, "That's so!" But when the text requires the reader to fasten a new concept in his mind, that's work; but I believe the former will prevail here over the latter, even with the number of new concepts.

REVIEW

It will be of advantage to summarize, which is virtually a review, the facts I have used in other parts for they can be more readily fixed and employed.

Void is where there is no matter. Empty space.

Matter, therefore, occupies space.

Energy, therefore, must occupy space.

Force, therefore, must occupy space.

Spirit, therefore, must occupy space.

For if these things do not occupy space they do not exist. Energy and force, if they do not exist in known tangible matter, must be in unknown matter associated with known tangible matter, and spirit must be a higher and more refined kind of matter, hence there are no discrepancies, no discord. From these follow the truth of what we have been using in the other chapters, viz.:

Energy is the capacity of the atom to act.

When atoms cohere it is cohesive energy.

When atoms repel it is repellent energy.

When atoms act their energy produces force.

Force, then, is matter in motion or cohering or repelling.

Therefore, in using these terms with this understanding we are dealing with known and tangible things; this is physical yet it is the metaphysical that does the understanding and the knowing.

Now this metaphysical enables us to conceive, for our pleasure, that possibly atoms have different shapes that account more readily for the wonders in crystallization; that they may really have other capacities than cohering and repelling to account for the wonderful change produced when they are combined in special molecules; as for instance, oxygen and hydrogen are very inflammable gases and their united blaze burns up iron, but when two hydrogen and one oxygen atoms are united in a molecule of water they extinguish fire. Yet affinity for Rx is a scientific explanation. And Rx may travel over conductors and in light like an arrow to account more closely for conduction and positive and negative electricity, for they only indicate quantity and direction of current.

By accepting the atom of that early thinker and philosopher Leucippus, but with the capacity within themselves to cohere and repel, we can have an inspiring conception of the wonderful molecules when they unite into molecular societies, and construct grass, trees, flowers, fruit and the sublime palace, the human anatomy.

THE MOLECULE

Atoms are the sand and mortar of nature of which molecules are made, and molecules are the bricks, stones and varied material of which mass is composed and individual plants and animals are built up. The atom is the unit of the chemist and the molecule the unit of the physicist, while the biologist combines the two.

The atom is the unit of the molecules and therefore is not as complex or numerous. The atom is the alphabet, the molecule the dictionary of words, and inorganic and organic nature the literature and library of a universe. There are twenty-six letters in the alphabet, but ninety atoms in the alphabet of nature, hence the greater variety and sublimer literature. When the simple truths of nature, shorn of the incubus of hypothesis, are taught from the kindergarten to the high school there may be so many inspired writers, orators and poets that there may not be enough left for auditors.

CO is carbonic oxide, the simplest possible molecule, one atom each of carbon and oxygen. H_2O is a water molecule, two atoms of hydrogen and one of oxygen. In the formula already given for glucose $C_6H_{12}O_6$ the figures express the number of each kind of atom in the molecule.

Chemistry is the most accurate and perfect of the sciences to the point it has attained, and my discoveries therefore affect it the least, which indicate the accuracy of the discoveries. The formulæ given are all incomplete for they should be COR, H_2OR, $C_6H_{12}O_6R$. R is for Rx which is in every molecule and that is why it was not before discovered and why it need not be expressed in formulæ. Since this is new and so many have studied chemistry I must prove it as well as explain.

In the chapter "Seeing Space" it was demonstrated that Rx of necessity is on the surface of every atom and molecule of a gas, which are bombarded by free Rx. The atmosphere is a compound gas, but principally a molecular gas, while oxygen and hydrogen are atomic gases just as a $20 gold piece is a compound, and pure gold, an atomic substance. Hence, mingling in a tank two volumes of hydrogen and one of oxygen gases they

will make a mingled gas of three volumes and they will remain distinct atomic gases forever. But drop a spark of electricity or fire, which is Rx, into the mixture and it will explode into water molecules and the gases have disappeared. Therefore no one will doubt the new fact, that of necessity Rx must be in every molecule, but the number of Rx atoms in a molecule, also of necessity, most likely can never be determined.

Let me again impress the importance of having clearly in mind the necessary and all important repellent function of Rx and it will immediately appear how illuminating this, not radical, but pacific discovery is, of Rx in every molecule.

CHEMICAL AFFINITY

Chemical affinity is now defined as, "that force which causes the atoms of matter to separate and unite into new compounds," which are composed of new molecules. But behold! it introduces a new force to be discovered, while with Rx and atoms we have all the forces there are or are needed. The new force is merely descriptive and does not involve any new factors or unknown processes as the old idea.

Chemical affinity is the breaking up of different molecules in a solution because of unequal tensions and forming new molecules according to the equilibrium of the cohesive tension of the atoms in the solution. It is longer but it tells the whole story, while the former is only the introduction of a mystery, the new force, the breaking down and the building up, all requiring new understanding to mean anything.

To illustrate this statement of the new molecular law: marble is composed of calcium, carbon and oxygen, $CaCO_3$, and hydrochloric acid HCl, hydrogen and

chlorine. If two parts of the acid be mingled with one of marble, the molecules will be torn down because of unequal tension and three compounds or molecules formed of equal tension; CO_2, carbonic acid gas, $CaCl_2$ calcium chloride, and H_2O water, each with three atoms, and there were just nine atoms in the acid and marble. Thus all is known about the physical atom that can be known until the microscope can reveal other facts as to its shape and how it is combined in the molecule.

To understand the above "chemical affinity," clearly, concretely recall the definition of Rx repelling its own atom and having a different cohesive strength for every other kind of atom. Cohesion is merely holding and the stronger must overcome the weaker. Hence the breaking up of the molecules is self-evident, and the repulsion of Rx drives them into combinations of equal strength or tension. No imagined "chemical force" is needed. "Nature" does things the simplest, wisest way. Whoever comprehends this has the key to nature's vast chemical laboratory, organic nature specially, and in the little biology that follows the reader must use it constantly with delightful satisfaction.

PROTOPLASM

The biologist and the dictionary say, "protoplasm is living matter," while I say that the molecule in formation according to the law is nearer living matter than the protoplasm as it is described and illustrated, believing that life is something higher than known physical law. This is, to be more explicit, that the formation of the molecule can be accounted for by the physical factors and forces of solids and gases that we know, while life cannot be.

At any rate my definition is more individual, for biology defines protoplasm as a compound, and that the elements are not the same in the protoplasm in different parts of the same organism while the prevailing constituents are proteids, mineral salts and water. A grain of corn and an egg fulfill these conditions but by the new law are not living matter, and as we shall see later are only in the condition for the rapid formation of molecules from which life results. Proteids are special compounds derived from plants and animals, and are composed of the kinds of molecules mentioned in the statement of the law, or of weak or unstable tension.

THE CELL

Cells are the microscopic spaces in the structure of vegetable and animal tissue and therefore must be estimated by the billions. There is no questioning of the existence of the cell, even by those who oppose the "cell theory," but they are understood and pictured as the factories and laboratories wherein are made the materials for the structure, growth, functions and motor activities of the individual; where the protoplasm is and reproduces. Their purposes are the points in doubt, for cells contain the solutions from which the molecule secures its supply of atoms. They form the structure and mechanism which constitute the individual through which the life expresses itself. That I have not incorrectly characterized the cell I quote the following from the eminent biologist, Arthur Dendy:

"Each cell may be looked upon as a microscopic laboratory in which the complex chemical reactions comprised under the term metabolism take place, and although, in the higher organisms, the cells have become mutually dependent one upon the other yet each retains a certain degree of physiological as well as morphological individuality."

LAW OF THE CELL

Cells are the form, structure and material of the law of the molecule.

It appears that the law of molecules applies equally to the cells for growth is a repetition of like cells. It furnishes a ready understanding of budding, as a bud appears to be a cell that does not have a special place in the regular structure and commences repetition outside of the regular form, hence by increased capillary force causes it to burst through the restraining bark and commence a new stem, resulting in a branch. The flowering buds only complicate the problem of reproduction which is discussed a little further on.

ORIGIN

The origin of the cell and protoplasm is one of the most fascinating fields of adventure for the evolutionist and is of universal interest. The general theory is that some one kind of cell and its protoplasm at some too dimly lighted date back in duration arrived on the earth from an outer state of existence and, falling into the proper environment, began to function, and from this single cell, like "primordial matter," all the millions of kinds of cell and protoplasm by evolution have been evolved.

This historic creature must have an appropriate name and hence has been christened "Cosmozoa," a citizen of the universe. But they have never been discovered, by man, hence they may have long since gone on to other worlds.

The date can partly be fixed for it was after "Time" was invented or started, for the earth was here "when" it arrived. But I fail to see wherein the materialist

gains from this assumption for the genesis of the cell and protoplasm need to be accounted for "from the state of their origin" as well as here. The sad result of my discoveries is the fact that the materialist can turn them largely to his account, but the comfort is that the final explanation leaves the physical laws helpless alone to make the explanation of what he beholds, complete life.

To him, therefore, this chapter should be pleasurable reading from the psychologically biological explanation given above for "work and play." That the reader may be assured of present concepts I make another quotation from Dendy:

"We have to imagine the whole organic world as consisting of a continuous stream of living protoplasm, which commenced to flow many millions of years ago and has continued without interruption ever since. At every cell-division the stream branches and physical continuity is more or less completely interrupted, but this in no way invalidates the conclusion that if all living things did not actually have a common origin in a single primordial protoplasmic unit, they probably at least originated from several such units which themselves arose under unknown conditions from inorganic matter."

The reason, of course, for throwing the first protoplasm so remotely distant into the gloom of yesterday is from fossil remains. But why be satisfied by our own condition when by it we determine the organic as differentiated from the inorganic, name the agent Life and yet cannot explain how life executes the difference. In other words, deny the superhuman around and within ourselves and admit its operation far in the past. For our investigations will bring us to this very conclusion.

This may be one of the short "work" places in the chapter for I will give some scientific names necessary in reaching our purpose.

AMŒBA

The Amœba is a one-cell protoplasm animal, microscopic and invisible to the unaided eye. The Amœba is not considered the smallest living thing but is perhaps the smallest animal with complete functioning within itself from beginning to end of life. I will therefore use the amœba as a functioning living organism to illustrate the necessary terms for the understanding of the operations of the law of moleculese and evidence of its correctness. It may be of assistance to just consider the big words directly to get a view of the diminutive animal found on the mud of ponds and ditches. The cell and protoplasm are the real topics, interesting and marvelous as the little creature is. Fig. 5 may aid the description.

FIG. 5. AMŒBA

A. B. The same individual in two active movements showing change of form.
C. Diagram of reproduction by fission.
C. V. Contractile vacuole: ect. ectoplasm. end. endoplasm or endosark; f. p. food particles; f. v. food vacuole; nu. nucleus; psd. pseudopodium. (Arrow shows general direction of movement) After Dendy.

Imagine a drop of clear jelly as an amœba, which it really appears to be, but magnify it to the size of a cherry. The whole thing is protoplasm, the skin or

outer layer is known as the ectoplasm and the contents endoplasm, in which float food particles and food in a sack, with a vacuole (air space) in it, and a contractile vacuole, a sack of clearer liquid, which disappears and returns after the manner of breathing; but the most important thing in the interior is the nucleus in a similar covering. This is a cell, protoplasm and amœba. It has no organs of locomotion but moves by projection of some part of the jelly body in the direction it would go and then contraction of the same. Or it may be construed as the effect of attraction in the environment, water, on the jelly mass that produces motion. The projected portion is known as the pseudopodium.

Its food is proteids from vegetable and animal origin which it absorbs by endosmosis through the ectoplasm skin as it passes over it and appears to reject undigestible matter it meets, and discharges the fæces, through the hinder portion by the principle of exosmosis.

The simple, minute drop of jelly protoplasm turns out to be a mechanism of parts, functioning by its own energy or that of its environment. It is a self-contained home, factory, incubator and processes, a protoplasmic cell, and cells are so small that there are thousands of them in a small section of a hair.

The vitality, life, of protoplasm in the amœba and tissue of plants and animals is now considered as the power of controlling chemical and physical processes which does not obtain in non-living matter unnamed, unknown, but "considered." Bear these in mind. For in addition to what has been said of this power in the amœba, in many of the lower plants and animals the cell protoplasm secretes a protective covering or skeleton of mineral substances, generally of wonderful symmetry, beauty and great variety. Thus the power of

choice (remember this) is attributed to protoplasm, which will be pointed out is not from life force or life energy even in either higher plants or animals.

HÆMATOCOCCUS

The Hæmatococcus is a one-cell protoplasm plant, typical member of the organized vegetable kingdom. I will give only the additional essentials differing from the amœba for the purpose of the chapter, for a complete proposition, aided by Fig. 6.

The cell is found in its active state in stagnant rain-water and in its "lifeless" state in dried-up mud and dust. In dense numbers it gives the water a bright red or greenish color, or a red crust on the sides of vessels. The chief reason it is considered a vegetable is because it can be dried and kept for years and will resume life activities when given rain-water and sunlight. These are important facts to be noted and which I will use when I explain the "power of choice" mentioned just above.

This colored drop of jelly protoplasm differs from the amœba first by having a somewhat crusted shell of cellulose, of pear-shape form, composed of carbon, hydrogen and oxygen the molecular former being $C_6H_{10}O_5$. That for sugar or glucose is $C_6H_{12}O_6$ and these are known as carbohydrates.

While the amœba and hæmatococcus require water for locomotion the former crawls on the bottom and the latter swims by means of two flagella, hairs, that branch from the pointed end of the pear-shaped cell.

The hæmatococcus shell contains the protoplasm which is red, green or mixed, and is surrounded by a clear fluid in which is a threaded network that attaches to the shell and thus keeps the protoplasm in position.

The flagella spring from the protoplasm and pass through two holes in the shell.

The green color is accounted for by the presence of chlorophyll by which the green of vegetation is now accounted. This is an illustration of how a scientific concept right or wrong propagates; like the "dust" sky

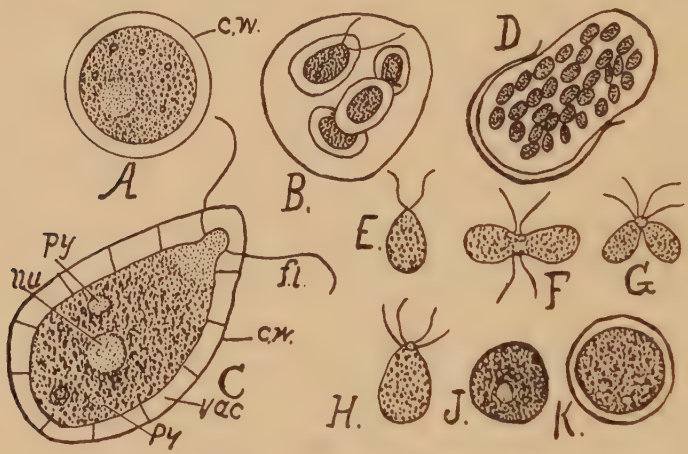

FIG. 6. HÆMATOCOCCUS

Structure and Life History

A. Resting stage with thick cell-wall.
B. Division into four motile zoospores within old cell-wall.
C. Free swimming zoopores.
D. Division of the resting cell into 32 microzooids or gamtes.
E. Free swimming gamtes.
F.—G. Conjugation of two gamtes.
H. Zygote with four flagella formed by conjunction.
J. Zygote with flagella withdrawn.
K. Resting cell formed from the zygote by a thick cell-wall.
cw. cell-wall; fl, flagellum; nu, nucleus; py. pyrenoid; vac. vacuole; (Fig. D. K. adapted from Pleeblees, the remainder from Dendy.

color. From the green of the spring and summer one must, if this is true, wonder where nature gets all her chlorine and what she does with it when the vast harvest fields are changed in a night into golden yellow. Another explanation will be found in its place, and that it is in agreement with the law of "The Color of Object" given in "Seeing Space."

As in the amœba, the important part is the nucleus for the propagation of the plant, but on a commercial basis there is a new and important substance in granules known as pyrenoids from which starch, a carbohydrate, is derived. Here is the commencement of that vital subject of foods, proteids, vitamines, calories, etc., that have become common, popular science and discussed in the public press as topics of general interest.

The importance of the nucleus here, as in the amœba and all animals, is that multiplication centers and takes place in a similar manner, by fission. The daughter cells are generated within the hard shell in pairs and sooner or later it disintegrates or bursts and the new generations known as zoospores begin their individual existence in the sustaining liquid solution.

Soon two of these zoospores will become attached by their two flagella, and in a short time the two will disappear into a single cell with four flagella protruding from the pear-shaped end and a repetition of the miniature drama of the hæmatococcus as outlined in form and processes of existence are resumed. If the water environment dries up their remains, for they are legion, are said to be in a resting condition, but not dead, and appear as dust or give color to the mud. The very logical explanation is that they are now merely the elements of matter in mechanical arrangement ready to start into functioning cycles whenever the physical forces can act, which will be the return of complete condition, a watery environment.

Of course all the factors and processes in animal and vegetable life are of importance for perpetual existence but we rate their importance by the wonder they inspire. And so now we are to note the most impressive fact and process in organized matter. The only explanation I

can find is in the principle of Rx and atomic energy. If one finds he has lost interest in these wonderful facts (for the author is not in this chapter nor the book for that matter) he has not secured a clear, working concept of gravitation and cohesion. For these facts are the property and machinery of our own existence, for the altruistic must first have interest in themselves to be of best service to others. If one studies the action of the atoms in water and cement, in swelling and melting ice and then when transferred as continuous actions of these minute actors in gravitation one will have interest in these facts and especially the principle of osmosis.

OSMOSIS

Two gases separated by a membrane or tissue will each pass through and mingle to an equilibrium. This is named osmosis. The food passing into the amœba is termed endosmosis and the matter thrown out by, exosmosis. But it is not confined to gases; two smooth pieces of lead and gold pressed together will in time penetrate atomically into each other. Wonderful! But the reader already has the facts for the Why? and How? in the attributes of the atom.

Capillarity is the first concept, and just this minute, for the first time, I discover that capillarity is the real gravitational action on the atom, moving it, while in gravity it is only in stress on the mass. (The reader will please pardon me for this frank confession and date; but this concept of truth is just that important to me.) Pores and capillaries are tubes with diameters of hairs and less, hence loose atoms can be drawn through them by the cohering atomic action.

To make the concept clear, the two gases or sub-

stances have unequal tensions, and Rx always seeks an equilibrium (it must stop them) hence they attract, and on account of the principle of capillarity the membrane is no hindrance. Then (although this is due later) the character of the tissue, as per the size of the pores and the affinity, may determine the kinds of atoms that pass, and we have a logical cause why a peach tree remains a peach tree and produces peaches, and birds, birds.

METABOLISM

The principle of osmosis is so near akin to and a part of metabolism that it is well to fix its understanding now. It embraces two terms, Anabolism and Katabolism, among the erudite scientists, but we can conceive it better by thinking of growing fat or getting lean. Anabolism applies to the growing boy and katabolism to the aged and the anæmic. When vitality is strong the molecules are in high tension and build others more readily, but when they lose vitality, tension, the tension of new atoms and molecules in the food is the stronger and tears down, first surplus tissue, fat, and finally affects the efficiency of the whole tissue. During maturity there appears to be an equilibrium of these forces. Hence anabolism expresses the fact that the tissue is increasing, and katabolism that tissue is being torn down, for metabolism means changes in organic matter.

MITOSIS

One other set of facts of the cell that will be of value later in the chapter, is related to cell division in the higher animals and known as Mitosis. It mainly concerns the nucleus and by taking our cherry drop of jelly of the amœba, calling the outside the cell-

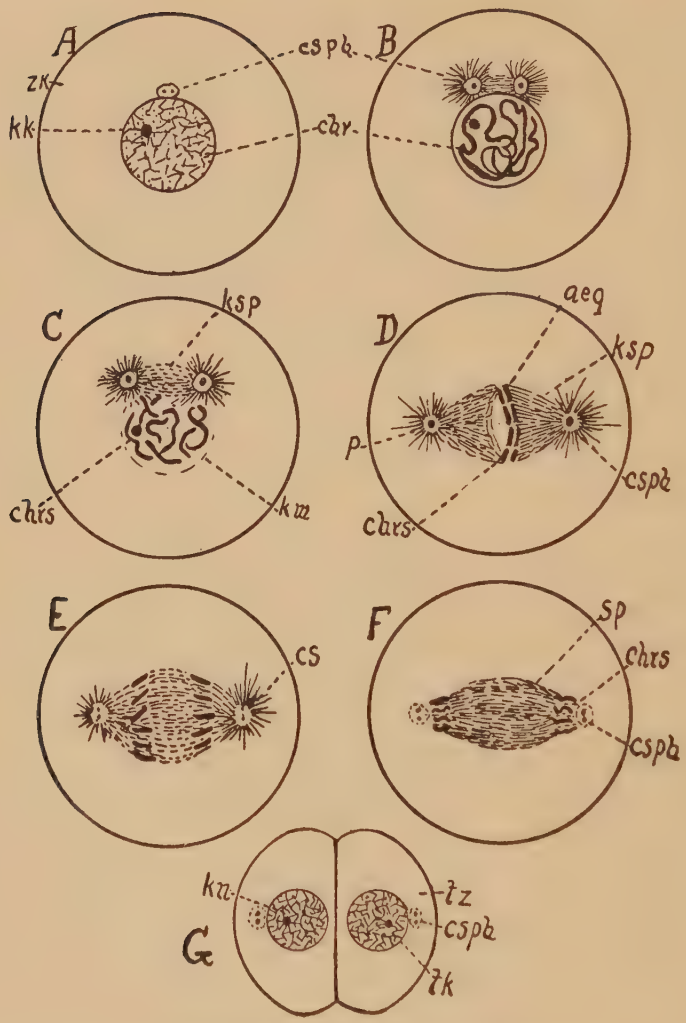

FIG. 7. DIAGRAM OF THE PRINCIPAL STAGES OF THE NUCLEUS OF A TYPICAL ANIMAL CELL.

(From Weismann's "Evolution Theory," adapted from Dendy.)

aeq. equatorial plate; chr. chromatin; chrs. chromosomes; cs. centrosomes; cshp. centrospheres, containing one or two centrosomes; kk. nucleolus; km. nuclear membrane; kn. nucleus; ksp, sp. nuclear spindle; p. aster; tk. daughter nucleus; tz. daughter cell; zk. cytoplasm forming the cell body.

membrane, and then suspending the nucleus as in the hæmatococcus, we have only the interior of the nucleus to study. (Fig. 7.)

The first important fact is that the nucleus contains a granular substance known as chromatin which undergoes remarkable changes. From the granular appearance in changes into a thread and the thread breaks up into segments, and the number is definite for each species of animals and plants.

Just outside the nucleus in the cytoplasm are two grains named centrosomes, of seeming more importance as they appear to control the chromatin, for these grains separate and a threaded connection joins them: Then the segments of chromatin arrange themselves equally between the grains, finally each segment will unite with its centrosome and the two combinations with two new centrosomes form new nuclei, the whole cell divides between them and the process is complete in two cells. Now it must be understood that the material and force for this transformation comes from the cytoplasm which is supplied from the plant or animal.

Even from the limited number of facts given the general reader can take an interest in the discussions of the naturalist and biologist in trying to draw the line of demarcation between the plant and animal kingdoms, and at the close of the chapter may have original ideas on the subject. For now we commence a direct application of the facts, not hypothetical understandings but known and measured facts, of the molecular law.

PHYSICAL LIFE

Physical life is such a related combination and mechanical arrangement of varying molecules, known as organized matter, *that when given the environmental*

conditions for their systematic co-ordinated cycles, from self-contained energy, repeat their cycles, increase to maturity and reproduce like embryonic organisms. Or,

The repetition of systematically related, mechanical, molecular cycles reproducing like organisms is physical life.

I deduce this definition from known facts for it naturally follows in the proof of the law of molecules, while perhaps it may be to many a new concept of what life really is. For I have two conceptions of what life is, and this is one, as far as I can take its explanation by known physical energy and force. This is as concrete and complete a definition of physical life to the point or stage of reproduction as a definition of a steam engine or a motor for the matter and forces are alike known. I am not, therefore, using hypotheses.

DIRECT APPLICATION

New Thoughts on Life

I have defined life above, but briefly, vegetable and animal life are recurring cycles of molecular mechanisms by physical laws. This means the common understanding of life when we speak of a live and dead plant, tree. But not one of the physical laws that sustained the life stops. They are synchronized in the living organism and are merely desynchronized in the dead. The latter continue until the elements are back to the unorganized natural state.

But I propound these questions: Is this common thing and concept life? Is not the real thing, life, a higher principle that maintains the laws in their cycles? If this is admitted all the problems of biology are explained, for it will soon develop that there is a problem as unsettled as the "original cell of protoplasm" which

science settles by saying it came to the earth from some outer source, while it is more probable that this physical life commenced here by a single molecule cycle, if evolution insists that life was not created.

Nor our equipment for making this application is the cohesive capacity of atoms by which they are built into molecules and molecules into forms and organisms. Second, we have the vital energy in the repellent force of Rx which has the double function of breaking down molecules into atoms and propelling atoms and molecules into activity. Therefore we have the advantage of all past biologists of being able to know and locate the active principle, the force that produces the motion and the commotion in the organic world. *The principle of life, however, is all that makes the difference of the inorganic,* for the same forces continue in the molecules disorganized when life ceases.

Therefore it is as essential that molecules be torn down as well as built up. Hence we must know *stable* and *unstable molecules of the organic.* The former are molecules that *resist* chemical action while functioning in a living organ. This is wonderful when we consider what chemical affinity accomplishes in digestion, while the organs do not digest themselves. The unstable are the digestible molecules.

Here I will make the first and a very forceful argument for the law of molecules. The organs build and replenish themselves, hence they are constructive and their molecules are what break up the unstable molecules, hence they are stable and maintain the organ. Therefore, if molecules are made in cells another explanation is hard to find to explain this fact in digestion alone.

Add to these fundamentals the absolute necessity of

contact of elements for every change and that solution is the way by which contacts can be secured. Although there are about 90 kinds of elemental atoms (about 65, forty years ago), organic nature uses mainly only five of them, viz.: Carbon, Oxygen, Hydrogen, Nitrogen and Rx the most essential has remained unknown through the centuries.

Inorganic molecules have but few atoms, 2 to 10, while the organic are most complex: some authorities giving the albumen molecule 222 atoms, $C_{72}H_{110}N_{18}SO_{22}$ while there may be over 250 Rx atoms that were not known, while they are now seen to be essential. The nature of the class of atoms indicate why organic molecules are so unstable and perish, disintegrate, as soon as life ceases to use them for they are all non-metals and gaseous. But the new and most lucid explanation is Rx, the hitherto unknown and most active atom in every molecule. This will be a pleasurable new fact to most chemists.

THE AMŒBA

My contention is that the protoplasm of the amœba is merely the atomic solution, and that the nucleus is the amœba, the mechanical arrangement of molecules by which the cycles of its life are accomplished like and by the forces in the marble and acid. The question of its origin is not in this discussion.

Osmosis, which is one of the mechanical life principles, accounts for its food since it absorbs unstable molecules and rejects the stable such as sand, because they could not be taken through the capillaries by disintegration. The breaking up of the molecules releases Rx which furnishes power for forced activities. (Place a lead pencil on a card and sharpen it with a sharp knife

and one may see this release of Rx in the behavior of the shavings.) Hence here is the force that flows electrically from positive to negative through the mechanism to produce the changes that constitute the life of the amœba. The mechanism of the nucleus must be the most single and simple, and of fewest cycles.

This may seem a short shift for so long a preparation, but if the preparation has become a vocabulary one will agree that this is luminous enough for all the delays.

HÆMATOCOCCUS

The facts of the amœba may be said of the hæmatococcus molecules. But the number makes no difference for like creates like. If the amœba is an animal, as is claimed, then the hæmatococcus is a more highly organized plant, if a plant.

The crusted shell here is another argument for the law, because the molecules must undoubtedly be made and used "onthespot" which is an essential of the law.

The locomotion is evident by the flagella, while in the amœba there are two views possible. The one now held is its power of discrimination as to food and motion. But the food has been shown as purely mechanical or physical and the same principle would lead it in the direction of food, unless it can be shown that it has a volition of its own.

The multiplication of each by fission should be considered only as a completion of the life processes.

This is too brief a discussion of the amœba and hæmatococcus from the lengthy preparation for its understanding for it is presuming all are as familiar with the new principles as I am after long study. This is too flattering to the reader and therefore I will pose long enough as a real Biologist to enlarge and set out

the principles. For these two creatures may epitomize the whole process of vegetable and animal growth.

It may be recalled that in the explanation of chemical affinity there was an illustration of molecular formation similar to that of the amœba and hæmatococcus without any life-principle that we wonder about so much. The marble and hydrochloric acid disassociated their atoms and formed new molecules without any organization, no "fuss and feathers," and the same would have continued as long as the supply lasted. The facts of cohesion and the repulsion of Rx supply all the force and explanation needed with the molecular law.

In the case of our two organized molecules, it appears that when a new molecule was formed it was separated by fission and the two commenced a repetition because the supply of atoms was at hand. Now the repulsion, cohesive and capillary functions of Rx furnish a possible understanding of automatic locomotion from the condition of environment, and the "chemical affinity principles" illustrated above, supply an explanation of the other changes.

This then is a case of a single cycle, and as for myself, it would not strain my imagination more to conceive a doubling and co-ordinating of cycles here on the earth, than to bring a "Cosmozoa" cell and protoplasm from some other earth.

All these are tangible and knowable facts which themselves compel the deduction I have made. The solutions in which we find the amœba and hæmatococcus are natural formations, and since these living molecule-cycles appear so quickly when these solutions are right, may they not be cases of spontaneous generation? If we knew there is a life-principle associated with atomic matter, it would be given as a cause of the appearance

of these creatures. And we will presently arrive at a point where we cannot account for the perpetuation of life-cycles without a life-principle. If it were not for this point we would have grounds for believing these cycles due solely to atomic and environmental conditions. For up to this barrier the facts of biology follow as readily as this explanation of the amœba.

THE MITOTIC CELL

The third cell was taken because it pertains to the higher animals and introduces more cycles. The nucleus is still important, but the germ or pattern seems to be in the centrosomes, for the cause of the changes in the chromatin originates from them. This cell plainly shows the electrical property of Rx for thread conductors are formed between the centrosomes between which the chromatin is equally divided when fission takes place. Now Rx would automatically flow between these as the Rx from disintegrated molecules was released, flowing to an equilibrium in this way supplies the force for new molecules. The constant disintegration of molecules furnishes a constant current of force flowing through the parts, building the structure to proportional sizes which cause the functioning observed in growing vegetation.

By carefully consulting the figures illustrating the amœba, hæmatococcus and mitotic cells which are reproduced from Arthur Dendy's biology, fairly good concepts of these processes may be secured and especially if one conceives the potential repulsion of Rx forcing the activities and circulating among the atoms, and then some Rx entering into cohesive partnership with atoms here and there, which accounts for the need of heat in both vegetable and animal growth, building

the permanent mechanism by a stronger cohesion than elsewhere, which is made possible by the measured and geometrical tensions of the atoms and Rx in the special molecule.

REPRODUCTION

We have arrived at a point where the evolutionist is as helpless as accounting for the first cell. For when he says it arrived from outer space that settles the point. He deports a deep sigh and exclaims, "Fine! That's out of the way!" Here is the organism completed out of the protoplasm, but how does the nucleus or the centrosomes produce a new pattern to go through its life cycles? For there are conditions in this "living protoplasm" or it fails. The law of molecules fails also to account for the new embryo. Rx can account for the crystals of the snowflake, the gem, the plum tree and the plum, the animal and its functions, when a sample molecule or a mechanism for cycle forces are given, but it cannot explain the origin or reproduction. The egg is given as the sample of protoplasm, but it will not develop unless fertile, and that is the "condition" in protoplasm, hence it is not life. The hæmatococcus dried up and kept for years may be considered protoplasm; it is not life, but it is rather preserved mechanism, and when the lacking condition, Rx in rain-water, is supplied the machine starts. Thus we can only explain up to this common barrier, and hope for its explanation later.

The scientist and the new reader can now get assured bearings. The names are all the old names, but the explanations are all new and understandable by the new principles of Rx and the new atom. For if the energy and the force of the water-molecule,

H_2OR are not in the atoms themselves there must be another energy-and-force-atom acting upon each of the four atoms holding them together, which is not as reasonable, for such a conception would destroy the individuality of each of the four, make them passive and quadruple the capacity of this fifth atom in doing what the four alone can accomplish, and space would have to be provided for the unneeded fifth atom.

How simple and sublime is this explanation to all who have a clear conception of these same principles acting in the case of gravitation, for these tiny atoms are made into molecules and controlled by the same forces that guide the mighty earth in its tremendous orbit. If this sentence is not clear and illuminating, it is because a clear concept of gravitation has not been secured. For, as Rx passes through mass the same tendency to action takes place, and this tendency is gravity.

I will briefly review, in preparation for the use of the egg and a grain of corn, to more clearly and directly illustrate the new definitions and functions of the laws of the molecule and physical life. At present biology holds that the molecules are built in the cells and that the force is in the protoplasm as living matter. Or, paying less attention than I do to the molecules, it does teach that in the cell the organism is reproduced by processes equivalent to those I have described. But we shall now see from the egg and the corn that molecules only are mechanically or physically produced and that the life principle has not been touched, as I account for all that the biologist has discovered, by the laws that govern the physicist in the explanation of physical phenomena, heat, light, electricity, force. Nor do I claim to explain the life force which I contend is not in the protoplasm. There certainly is a life principle in the

cohesive and repellent capacity of the atoms by which they cohere and repel, and by which I carry my explanation as far as I do, but it stops just where I contend the biologist stops, and to go farther is at present, at least, only by means of hypotheses. The biologist assumes protoplasm as living matter; I take the molecule and a miniature organism, and for the two purposes, viz.: the law of the molecule and physical life in a physical organism. Hence if protoplasm is living matter there must be another entity there that is not named, yet it is not needed in my explanation, therefore is it there?

In allowing my manuscript to be read, I find the complaint that I am too brief in explanation, but when I examine the reader I find that he has not made the new concepts his own, his stock in trade. As soon as he grasps them then the explanation is clear and long enough. For example, the last sentence in the above paragraph involves six to ten new concepts to make it clear.

THE EGG AND CORN

The egg is given by the biologists as a sample protoplasmic cell. My position is that the egg contains an embryonic chick, composed of the least number of molecules for its related cycles, and that what is called protoplasm is merely the solution of atoms named in the law of molecules, and just enough by the law to increase the miniature chick to the size of the egg shell, when it is capable of shifting for itself in the way of food from which its molecular mechanism will continue by the same processes to increase the chick to maturity.

It will not conflict with the statement of physical life to consider the solution as the number of completed

molecules, that by circulation would find their proper positions in the chick. Nor does it conflict that the chick does not increase uniformly in all parts.

My position further is that the egg was not alive before germination started, therefore it could not be living matter, protoplasm. This and many statements for a like purpose are made to keep my promise, in the beginning of the book, to avoid hypotheses, and I do stop at a point where one is needed to proceed further. And my purpose here, to state it concisely, is to show that we do account by physical laws for physical life as now understood, while there must be therefore a higher life in higher animals, and is even necessary to complete the understanding of the physical, in the vegetable as well.

Hence the egg had to be fertile, and yet it could not be distinguished from the stale. A close simile to the egg is a storage battery; as soon as a contact is made it commences to work, and the connecting wire is called a "live" wire. Thus when heat, Rx, the same element, is supplied the current in the egg begins to flow and we say it is alive. And it is this identical battery current and force in all organized nature that produces all the phenomena of life.

The life of the chick after it emerges from the shell differs only in the matter and manner of securing atomic material for growth. It has to consume quantities and have a very complex solution from which the molecule selects, by the law, just what atoms are needed and the foreign have to be eliminated, but in the shell there are no foreign atoms and the miniature is protected from all interference.

For an illustration of vegetable life and germination the grain of corn is most apt and varies in only one

particular, that of moisture. The miniature plant is embedded and connected with a mass of just the quantity and kinds of atoms or molecules needed to increase its size to where it is strong enough to procure its supplies from its environment by the new physical forces, and if they are not there it perishes.

Note the two wise provisions, each different, yet for the same purpose: the water in the case of the corn and the temperature in the case of the egg. In the corn, to be sure of the environment for fruition (if not for the higher purpose of human food), and, in the egg, when the instinct of the parent desired its fruition. "Evolution" surely never lacked foresight in providing for future contingencies.

But the commencement of the functioning of the plant has one other wise provision, viz., that it is still assisted for some time from the solution. For as soon as the roots reach their new environment they at once begin to function. By capillarity they begin to extract atomic food from the soil and the cotyledons begin to evaporate the extra water that conveys the atomic material up through the cells of the plant, and this is their chief office, for they keep open the channels of traffic in the commerce of material. It is commonly considered that the dew on vegetation is condensed from the air, for they sing, "as early falls the dew," while it is more often from the plant keeping the channels open. Why growth is more rapid at night at times is that the current is rich but slower.

The new conception makes this commerce of material atoms the chief office of the cells, for they are the capillaries, and the growth of the plant; the tissues are cells just like those which made them and since they are alike, the molecules, according to the law, made like

molecules and there are more channels opened to commerce. Hence they are not minute and elaborate chemical laboratories, but channels for this traffic, and atoms are selected and molecules made and cemented in place, "onthespot," as has already been pointed out.

The laboratory business of the cell is to help select the atoms by osmosis, and this is what determines the special tissue of each plant. This "onthespot" idea is quite conclusively confirmed by the root going downward and along moist places, and the stem upward. This new scientific explanation of the growth of a tree may affect current literary similes, but I believe others equally as good will be found to agree with the facts of nature. Therefore no life law is required to send the roots down and the stem upward.

Glands strengthen "onthespot," while being nearly a sufficient confirmation of the law, for they continue producing like molecules, and what are needed in growth are thrown off as long as the supply of atomic material is present for making the molecules. Milk is this abundant molecule. The supply of the lacteal food of commerce quite closes the debate on the "Law of Molecules."

The apple is another good illustration of "onthespot," for the pulp is what determines the size, and the conditions for new molecules are only at the surface and beneath the skin. Hence the sap merely passes through the pulp to that position. The growth of the apple tree itself is an equal illustration.

The "miniature" premise is not original but it is one of the only two possible. The other premise is known as "epigenesis," and the miniature is claimed by the "preformationists," while the epigenesis' view contend that, in processes of development, the different parts of

the chick gradually take their form from the material of the undifferentiated protoplasmic ovum. I accept the complete miniature for, as a first impression, epigenesis seems hopeless from the greater complexity and need of directing intelligence, while the other conforms readily to known laws. But starting with each from the beginning, the trouble encountered in producing the miniature quite ruins grounds for choice between the "miniature" and "epigenesis."

THE SEED

The production of the Miniature, the Embryo in the seed, is the untouched barrier to science and evolution. It is more stubborn than the original protoplasmic cell. No law has been discovered nor even clue found. This chapter leads up to this Barrier by a broad, plain road, by clear guide boards of laws only to read across the Barrier Mystery, Life is Divine.

At the close of a condensed philosophy on the seed, Dr. Frank Crane closes with words that depict the significance of the above conclusion:

"If I were going to be a heathen man and seek in nature some object to worship as God, some object embodying the infinite mystery of life, I should worship the seed."

MENDELIAN PRINCIPLE

As a first impression the horticulturist may think that the Mendelian principles (Mendel's discoveries in hybridization) conflict with the law of molecules, while they rather confirm it. For all hybrid plants sooner or later revert to the original, which is strong support for the "miniature" premise. Perhaps the most direct evidence is furnished by the practical and marvelous results secured by Arthur Burbank. Wonderful hybrids! Thornless cacti, stoneless prunes, white blackberries,

etc. I cannot do more here than excite interest in this wonderful subject, but it can be gratified more completely elsewhere, while the general public is well posted on Professor Burbank's achievements.

Mendel experimented in his garden with different varieties of plants as, for instance, smooth and wrinkled, green and yellow peas, and found certain principles to prevail. Burbank crossed different varieties to procure the most desirable qualities, largely employing shrubs and trees, where propagation can be continued from buds. For, as I have remarked, in a state of nature they revert to the primitive. The achievements of these scientists are very valuable, especially of the latter in their vast practical, commercial value.

GRAFTING

Grafting supports my claim that the chief office of the cell is capillarity for the commerce in atoms. Tissue is essential to give form and individual expression to all forms of life, and the law of molecules permits each of these two offices to be perfect while a laboratory function would scarcely admit of this. Grafting is limited to the genus, a strong point, because of the principle of tension. Then one trunk of a variety may furnish the same sap for a number of kinds of molecular cells as plums, peaches, cherries, apricots, on the branches of a single tree, indicating clearly that the molecule is made and used "onthespot," for otherwise this surprising fact cannot be accounted for without hypotheses.

The repair of tissue, both in the vegetable and animal, even more than growth, indicates that the molecules are formed and cohered into position at the same point. For severe lacerations of the human flesh heal perfectly, and scars merely indicate that the supply

of atomic solution was not sufficient. And grafted skin is identical with the kind added.

It is the same thing to conceive that cells build adjacent cells from the law of like producing like which are the structures of the tissue, and for a like purpose of holding the solution and increasing the capillaries, for the whole cell is of one kind of molecule. It is only a systematic and cyclic use of the principle illustrated at the beginning of the marble and hydrochloric acid atoms.

The grain of corn surely completely discredits the "epigenesis" theory, for there is no opportunity for differentiated parts to find their positions which might be true in the egg, yet it would seem they are all miniatures or all by epigenesis.

It may have been observed that actual "contact" of material elements for effects has been a "hobby" with me, but it is a positive necessity and an axiomatic law. My repeated notice may be the reaction of my text-book training which required me to conceive cohesion to act at "insensible" distances (not quite touching) and then to act across 93 million miles of space as the gravitation of the sun, while the truth is that cohesion is by contact and the sun shoots vast quantities of Rx into the earth, and then after actual "contact" the sublime force of gravitation manifests itself. Always demand *"contact."*

HIGHER ANIMAL CELL

The periods of gestation in animals, as well as the conditions, are evidences that the full amount of atomic or molecular elements for a complete miniature organism to the stage of self-functioning are not already stored in a dry or liquid solution, as in the seed and

egg, nor all of the necessary elements in one, but divided in two separate and distinct individual bodies. A complete miniature therefore does not exist until the separate parts are united. The sublime, inscrutable fact produces such a hopeless situation for the evolutionist and biologist that it only illustrates the daring ambition of man in pursuing a solution. I forecast that the discovery of Rx will stimulate the search, and while it may lead to something nearer, I do not expect a mechanical or a material answer to be found.

Turning from the general to the specific, take the human embryo and a primal miniature germ is evidenced by the identity of parts in all races of mankind. This perhaps is the strongest evidence for pre-formation, for it is hardly possible that the exact number of bones, muscles and various tissues could so long remain constant by any other principle than that of an exact and unvarying pattern. For the sublime marvel is that the perfect human anatomy has remained so perfectly exact through the known thousands of years, functioning under such diverse and varying conditions of environment, climate, food and activities. Vestiginal (functionless) bones in so many animals indicate a fixed and uniform miniature embryo, rather than evidence of evolution. For by the exploited principle they should disappear in a very short time, or at least show a marked digression.

But the marvel is doubled when we consider the complete miniature is divided between two separate and distinct bodies. Yet this strengthens, if it does not prove, the functioning miniature, since it cannot commence until the embryo is complete, while epigenesis completes the miniature after germination. But epigenesis may have its seeming observable evidence in

this, unless the former is modified by a "working" miniature, or that all the miniature does not equally increase as does the adult.

These considerations do not change the law of molecules or "onthespot" principle. Or there is the possibility that there are places where two different molecules would produce a different molecule, as, for instance, a conjunction. While this may account for the cutis forming the nails, in which case it is evidence of "onthespot" principle.

The "onthespot" principle may seem to fail in the growth of the child, if it be conceived that the molecules from the mother, say of the hand, are made in her hand and carried to the growing child. But during this period it is evident that the whole anatomy of the mother is specially active, and these extra molecules would certainly find their only places and strong cohesion in the like parts of the child. For the growth is somewhat affected after birth when the atomic material is procured from its own digestion.

This view readily accounts for stature and racial distinctions, resemblance and characteristics of the offspring, and even for heredity of weaknesses that do not become pronounced in the immediate generations. What more or quite sufficient evidence of "onthespot" principle than that of the gradual change in flesh appearance with advancing age. It remains constant and new tissue is not that of youth, but identical with that of the condition at whatever age. The disappearance of scars is quite as final evidence. The water of Ponce de Leon's "fountain of youth," wherever it is, would have to disqualify this principle.

At first I thought that maturity was a barrier to the law, but it is scientifically accounted for in animals by

the fact that the nervous force is the same force that builds the molecules, which is the electricity-function of Rx, and this must have its special tension in each organism, and there comes a point when this tension is just sufficient to maintain the activities of the body. Its excess up to this point is the energy that has effected the growth, for growth is at first rapid and slows down gradually to maturity. At this point the molecules of the bones, the rigid parts, would become fixed, hence stature stops, and thereafter growth and lack of growth, getting thin or fat are due to this principle of tension together with food and other conditions. The methods employed to gain flesh support the tension explanation. It is this electricity tension in the gray matter of the medulla oblongata that controls respiration and explains why the breath is only limitedly under the control of the will. It determines the regularity and force under the varying activity of the body. But we must bow to the mystery of the miniature.

Were there no Bible to declare the fact, the inscrutable and transcendently sublime mystery of the office and function of the downy pollen of the antlers in vegetable economy should compel every matured and unbiased mind to exclaim, There must be a Creator! For while finite intelligence beholds faultless design, its intricate execution appeals to the same mind, the impossible. By speculation one may secure a satisfying cosmology, work out some plausible psychology and conceive of spirits and their habitations, but the human intellect stands baffled and silenced before the fact that the atomic flour of the stalk's tassel mingling in the silken tresses of the ear functions in the future life of the grains of corn. Even Rx that has spelled out into words so many of the elusive phenomena of nature has

no answer save its mere functioning in the production of the divine mystery.

BACTERIA

Bacteria are molecules that have or may not have part in any special patterned and sterotyped organism, that in accordance with the law multiply arithmetically when the conditions are present, and the bacteriologist produces the conditions in what are known as cultures.

Bacterium and bacillus are considered as one-celled plants or Schizomycetes because they increase by fission or subdivision, and may this not be merely the formation of new molecules by the law? They are generally known as fungoid plants, or by some as animalcules. They are of numerous kinds and some very useful if not necessary in plant and animal life, while those are harmful which prey upon the atoms required for normal growth.

SPONTANEOUS GENERATION

This is a much debated question, but science has concluded from exhaustive tests that no living organ has been obtained except from already existing life. The law of molecules may change this view, for we know there are spontaneous production of molecules. Whenever COR, CO_2R and H_2OR atoms meet they spontaneously form carbonicoxide, carbonic acid, and water molecules from their own inherent energy.

Therefore since we know that in inorganic nature molecules form themselves from their own inherent energy, and since we have seen that in organic nature molecules duplicate themselves by the same energy, it is scientific to conceive that a group of molecules could form, become distinct by a special tension and arrange-

ment of the atoms, and that this compound molecule or mass in the like environment would duplicate itself, and in this way a primitive organism formed through which the nervous energy or Rx would flow as heat and electricity over and through conductors and we would have the original "protoplasmic cell."

Hence the evolutionist, to avoid a Creator, would not need his "Cosmozoa" atom from outer space, for it must needs to have had some such kind of an origin if evolution is true, besides avoiding the vicissitudes and hazards of space. This could not apply to the rapid appearance of miniature life contemplated in the subject.

GERM THEORY

The popular war on germs, of these modern days, may find a concrete understanding in this molecular law. These germs are only molecules, bacteria, and when they fall into environment stated in the law they commence their multiplication.

Do not contagious and infectious diseases fall readily under the law? Croup is an excessive production of useful molecules that the system cannot throw off in the regular manner. Scarlet fever is a foreign molecule in the fertile solution for its increase and thus its fatal effects. Variola or smallpox appears to be a molecule that finds its limited solution in "pockets" or pores of the skin and by their presence they produce sores by which they are eliminated if the system proves able. Hence the supply limits its period of activity.

The immune state of the body when it is in a perfectly normal condition is evidence of the rigidity and individuality of the organic molecule, and the immunity from a second attack as well as the greater susceptibility in other cases are each consequential, for the former

changes the condition for their propagation and the latter makes it a more sensitive solution for the increase of molecules.

CLASSES OF MOLECULES

Because of the three classes of envelopes in all organisms it is supposed that each of these is a distinct germ tissue and has been named the epiblast or outer skin covering, from which the nervous system develops and, of course, terminating in the brain tissue. From the hypoblast layer of tissue spring the alimentary canal and the glands and parts of the digestive system. The mesoblast tissue is concerned with the skeletal and connective parts, blood vessels and reproductive organs. This is indicative of the relationship of molecules and of grades of cohesive tension that tend to keep the parts distinctive, and strengthens the conception of the law of molecules.

It is tempting in all the many cases like the above to continue the subject as though writing a biology, but they are all for the *one* purpose of revealing the distinctiveness of the molecule and its law of perpetuity.

I really believe that there are but few (and they are mainly those who have long-set convictions of their own on these questions) who will not regret my too brief discussion of these wonderful topics. But I am compensated by the fact that I have given them the keys by which they themselves can unlock the doors to all the physical problems they meet that are accessible to purely physical laws. After my Editor, Francis J. Casey, had completed this study of the cell and new molecular law, he made this comprehensive summary: "I see that you have demonstrated that the cell depends upon the principles of the molecules and not the molecule on the

cell." For the molecular principle determines the structure of the cell.

It is fortunate that scientists are already divided over the "Cell Theory" because I may secure assistance from the pros to ward the attacks of the cons. But the last topic carries us over the line a little into the field of the metaphysical. It is tempting to launch out into it somewhat. But I can touch only on the one topic where the simon pure evolutionist is hopelessly lost by the stupendous fact in the middle of it, which is the possession of the unsolved fact of instinct, and the total lack of instinct.

INSTINCT

Although some maintain that certain plants have instinct, all the cases I have been able to investigate are accounted for by physical conditions. But the instinct of animals and the lack of it in mankind is the unsurmountable barrier for undirected evolution and the all-sufficient support of a Creator. For I have shown that the merely physical existence of plants, animals and man can be understood up to the point of the creation of the miniature embryo and instinct, by the laws that govern all physical phenomena.

The solar system and, apparently, the sidereal universe, are maintaining their sublime evolutions by their own inherent energies, but must as inevitably as man himself, be under control of an all-sufficient Intelligence; otherwise it would be exactly like the human anatomy devoid of thought and reason. The forces alone could never have brought about the ordered and sublime universe we behold. While admitting the facts of evolution as freely as all other facts, I would need to discredit my own reason to believe that the blind,

impartial physical laws have, undirected, by the fortunes of chance, produced a universe of such sublime permanence, utility and purpose.

I feel entitled to this declaration for all others have explained and understood this whole panorama only by thousands of hypotheses while I have explained them categorically to a nearer finality than ever before without hypotheses.

The instinct of animals is unexplained, yet a design is just as evident as its marvel is sublime. The animal is born with all the knowledge needed throughout its whole life.

The lack of instinct in man is just as transcendentally sublime in evident design, for thereby man becomes the creator of his real individuality above, and which functions through the physical. This could not be so if man were not a law unto himself. Heredity and environment do have their effects pro and con but he is so potential in his capacity over himself that nothing but himself can prevent him from pronouncing his creation "good." He is superior in all stages of civilizations to heredity and environment. They are natural but insufficient excuses to avoid responsibility.

The instinct of animals is evidence of a complete miniature. For there must be some entity of instinct, knowledge, stored in the brain of the animal at birth. Human knowledge is all acquired, built into the brain with a common or psychic molecule, and becomes memory, the character, the real individual. Convictions indicate this perfectly, for when one discovers that a conviction, a supposed fact, is false, a new conviction is formed and controls but the presence of the old remains, and in many cases controls as is proven by false impressions as to directions. Hence man builds

his own mental mechanism and is able to change, modify and perfect, while the animals' is fixed and can only be added to limitedly by experience.

A SIDE LIGHT

The new laws of molecules and the fact of a miniature may furnish a clue to large families and more directly to small and decreased birth rate as nations become rich and highly civilized (if civilized is the proper word). The former follows readily from simple, natural foods and natural habits, while the so-called civilized seem "naturally" to tamper with nature. Great variety and highly seasoned foods may disorganize the essential atomic solution of reproductive molecules. The soil for vegetable growth can be recognized in the harvest. History reveals the conditions and the results, and all are in accord with these probable causes.

A PSYCHIC ATOM

We have studied the physical atom of the physical molecule, but here is the place to ask, is there a psychic atom of mentality or the soul as suggested by Democritus? Is it the atom of the spiritual matter, which constitutes the imperishable individuality? I am debarred from entering into a discussion of the questions for I have been dealing only with tangible and sense-attested facts while here I would require suppositions. But in thus passing the subject we must yield the palm to Democritus for he carried his atom so far, hypothetically at least, as to account for the Olympian gods, which surely could not have been any more unreasonable than the modern "electron atom."

Here again is the debating ground as to the boundary

of the vegetable and animal kingdoms but I will leave that for others or the reader.

The "demarcation" or newness of this biological survey is found in the definite location and specification of the energy and the forces that govern in vegetable and animal life as far as the actual physical is concerned. And this force is found to be the same as governs in the phenomena of nature outside of the living organisms. When we see sap ascending from the roots we see the cohesive action of Rx and atoms in motion through the cells by the principle of osmosis; when we see molecules made and built into the growing stem and flower, we recognize the atoms themselves furnishing the energy and cohesive force for the structure just as seen in a molecule of water, when we see a muscle move we know a current of Rx has acted upon the tissue just as in capillary and gravitational action; when we see the nucleus, centrosomes, chromatin going through their evolutions in the endoplasmic solution we note that Rx is released in unstable molecules and, repelled over the conductors, builds up more stable molecules into a mechanical organism through which Rx may maintain and repeat cyclic evolutions with other supplies of atoms; we see that these organisms are built out of molecules and how by the law of molecules they reproduce their kind, and these co-ordinated cycles in mechanically constructed organisms we understand as physical life.

But we do not see and do not know how an organism breaks the chain of cycles and at a single place produces a miniature, embryonic organism with its great number of distinct molecules representing the varied parts of the whole; we do not see how, as in the egg and the corn, the exact quantity of elemental atoms is stored, that

will build this helpless miniature into such dimensions that the cycles can themselves gather their materials from heterogenous supplies; but our helplessness is bewildered when we come to explain the instinct of animals and completely lost when we reflect upon our own mentality.

The perfection in wisdom and goodness of the Creator has its sublimest evidence in man himself, a creation so near in approach to Himself, that he is not only capable of so closely comprehending His handiwork, but is so equipped and endowed that he becomes the creator of his own personality by which to enjoy the greater blessing He still has in store for him.

Granting the atheistic evolutionist whatever age he may give the earth, without these distant and involved problems his own erudition is defeated by the unanswerable fact of the present moment. I care not to what dimensions he expands the mighty Betelgeuse, by the present law of gravitation the solar system and the sidereal universe should have long ago been collected into one universal unit of mass. In the cohesion of atoms and the repulsion of Rx science has the greatest combination of keys ever given to solve the problems of nature, but I am helpless without a Creator still ruling in His universe. We cannot account for the great number of missing links in genera and species of both plants and animals, the still closer problems of the miniature embryo, the instinct of animals and the mind of man.

CHAPTER VI

NERVOUS FORCE FROM "NEW PHILOSOPHY"

WE are nearing the conclusion of the New Philosophy and have arrived at that point to which a number of promises have been deferred. I am aware that this is a new subject in Physics, but I feel confident that it will be found proper, interesting and profitable. Most properly a New Philosophy would afford many opportunities for new declarations, and there have been so many in this work that the reader may be immune to surprise, otherwise this subject would admit of a climax in that particular. Yet it is not an artfully contrived climax, the stock in trade of the novelist and dramatist, but most naturally falls in importance and logical development to this position.

The common rule in human affairs is to improve every opportunity, and especially those that from their very nature are not expected to repeat their visits. All readers of this work have renewing opportunity to, not only investigate the declarations, but to pass upon the personality that made them. This is my only opportunity to enumerate factors that do not appear in the text, and since other personalities are involved it is most proper for me to be a little personal, and it is expedient, if not scientific, since it is argumentative. Therefore before taking up the subject and material argument, to which this is a support, I must express my extreme pleasure in the present situation for it is so different from most of the others, because it does not involve the contrary and seemingly established declarations of others. Up to this point I have been obliged

not only to take issue with the most illustrious names of the past in physical philosophy, but antagonize the convictions of the scientific world of to-day. The latter being due to the errors of the former because of insufficient data, is all too little accredited by the latter, and hence the situation is nearly alike for each. For by the living many of these illustrious names are held in inspiring if not venerated memory, and to some they are argument. While these cannot be factors in the test of truth, nevertheless they may, as they always have, hasten or retard the general recognition of the truth.

I have realized this situation from the first, not merely as a fact of history, but from my own brief experience, and have before attempted to eliminate the personal equation. Of course there never was such a wholesale order issued against scientific convictions, but which is easily accounted for by the fact of the error of a fundamental hypothesis, "The Ether," and with this recognition nine-tenths of the accessory convictions can be given up with a feeling of pleasure. In the case of the Law of Gravitation, I have been given as an argument that it was discovered by Newton, by those who reject Newton's "corpuscular theory" of light which is, to say the least, not consistent. They look upon my situation as though accusing Newton of making mistakes, while he did not, the trouble being with the insufficient and inaccurate data then available, and does not affect his credit in discovering the law. I defend this materiality of light and therefore acknowledge a greater credit than they do. This has no bearing on the facts of science, but concerns its progress.

Only professional science is posted on this phase of progress of knowledge. It is not generally known outside of scientific circles that Roentgen's claim for

X-rays was not only not accepted by professional science for two years, but opposition was in evidence, and some think that it was because of the personal equation. Then to think that it took science as a whole 52 years to accept Roemer's declaration, that light was not instantaneously propagated, but had a velocity of 186,000 miles per second, while there is not an argument that can be brought against the accuracy of the test or the certainty of the conclusion. There is not so much wonder that it was 60 years after Rumford and Davy's experiments before the acceptance of the "motion theory" of heat, for there was much as conclusive evidence for Caloric. Is it any wonder, then, in the light of this history, that I should speculate as to how long the "tenacity of old ideas" (Prof. Lowell) will keep professional science from acknowledging the claims of Rx? I have reviewed this history, to stimulate an early investigation and test of the claims of rex, for I do not desire the temporary triumph secured by the "motion theory."

But no conflict is precipitated by this closing chapter. It is all new and I can take the pleasure in presenting the claims for the conclusion that is intimated in the title of the chapter.

ELECTRICITY IS THE NERVOUS FORCE OF ANIMAL LIFE

There will be scores of claimants for the honor of making this discovery first. For doubtless a majority of all who have been conversant with the principles of electricity and nervous force have harbored the conviction that they are one and the same. But surely the establishment of the truth of the declaration, if I succeed, belongs to this the initial issue of the New Philosophy, because it will require all the new fundamental

and many of the accessory principles developed in this work to establish the truth of the declaration. Therefore it could not have been so proven prior to this time. Then this fact established carries confirmation of quite all of the new developments.

But it is necessary at the outset to say that science has declared, after making an exhaustive examination and testing, has gone on record to the effect that Electricity and the Nervous Force are not one and the same. This of course applies to the present conception of both electricity and the nervous force, and here I agree with them, for I have already proven that there is no "Ether" and there could be no "Ether" electricity. But my declaration involves the electricity as demonstrated in this work.

In the early part of the work I affirmed that Nature could not use electricity in her vegetable or inorganic kingdoms, and that I would demonstrate a higher use of electricity than any now recognized. The last is here fulfilled, which by inference corroborates the others. There will be attempts to include vegetation, but it cannot succeed. There seems to be a flow and circuit in vegetable life, but it is merely that of heat. There is no electric current without a pressure. The motions of sensitive plants are due to the Rx tension that is present everywhere because of the presence of the atmospheric tension as illustrated in the chapter on Electricity in the production of currents by the readjustment of objects.

It is now claimed that the temperature of the body is maintained by the combustion of food in the stomach, and from the oxygen taken from the air by the lungs. This is so settled that it is not merely a scientific understanding but one of the most common beliefs that

oxygen is the element that produces the supply of heat. I shall therefore first prove that the temperature cannot be thus maintained, and then it will be more readily seen that electricity must be the real source. For we have a new understanding of Heat and of Electricity, and in the chapter on the latter it was shown how heat is so readily obtained from the electric current. Thus the value in this closing chapter will be increased above the subject itself by applying most of the principles of all the subjects.

In the first place it is entirely out of the question that the slightly varying temperature of the blood in all human beings at 98.5° Fahr. in all climates can be maintained on the principles of cumbustion where conditions are so variable, and to such extremes. Disease is the only thing that makes a marked variation in the temperature for which oxygen cannot furnish an explanation, while electricity as the nervous force has a logical and complete answer.

The same almost exact temperature prevails with the Esquimo and the Hottentot, in the frigid and torrid zones. But the extremes are even greater in the temperate zones, but winter and summer the variation is negligible. This is taking into account the physiological means for regulating the quantity received by the body. The more one contemplates the even temperature of the blood of mankind the more will he be impressed as to the single origin of the human family and the fact of a Creative design. But the same result obtains from a consideration of animal life, snakes, fishes and birds, and especially the hibernation of certain animals. Some make their Creator and Evolution harmonize. I differentiate between them thus: A man plans his house and then builds it, and when he moves

in he finds that everything is perfect, that he has not omitted a single essential thing of utility and beauty. Another commences to build a place to live in, and after various attempts and improvements he moves in, and then discovers there are too many windows here and not enough in some other place, no fireplace, the kitchen is in the wrong part of the house, it is over or unbalanced, and he proceeds to make changes, adds an ell, makes windows, adds a mansard roof, and after all his changes finds that he can still change, and must to make it perfect. The former is my Creator and the latter my Evolution.

It would seem that I have already overdone the business of eliminating the "motion theory" of heat, but the truth is, that it will not hold accurately in any application, and the nearest are the experiments that resulted in its triumph. But it will enforce the present subject to "eliminate" it once more. With the understanding of that theory, why is oxygen a source of heat? There are only two possible answers; First oxygen must have more motion than any other atom, or second, it must have a greater capacity for compelling other atoms to vibrate faster or with greater amplitude. There are no others, and had these been thought out and the barrier to the "motion theory" discovered they might have found the atom of this philosophy, Rx. For neither of these are available as the phenomena of oxygen takes place alike when it is hot or very cold, i. e., great or little motion. And the second is the sole and fundamental requirement of the New, and inherent capacity to act upon contact, which, while the Old has vast quantities of atomic actions, it declares the atom is inert, and therefore must of necessity conceive of some other entity acting and performing the actions upon the

labeled atom. Thus there is no such thing as "Inertia," and its supposed existence has been a barrier in the path of progress.

Then this barrier would have been surely great enough to have side-tracked the theory, had the founders attempted to solve the fact that oxygen combined with hydrogen prevents and extinguishes fire, and becomes a ravenous consumer of heat. It is obvious that the founders of the theory did not find these problems, and with the misinterpretation of their beautiful experiments, and the "mechanical equivalent of heat" having no opposition the pronouncement of the theory was established by default.

But it will not do not to repeat the office and utility of oxygen for it is so common and takes part, or is present with, so many phenomena and being a new conception is not easily remembered with so many new things. Oxygen is present with all common cumbustion, and the two causes for its availability are the quantity of Rx it holds with a weak tenacity, and its capacity to form molecules with so many other elements. Therefore the error in using it as a source of heat is very natural and allowable, and without the advent of Rx I would attempt no change. But that it is not essential to heat is proven by the heat of an electrical current without even the presence of oxygen —alone quite sufficient to sustain my contentions.

There is more oxygen in the exhaled breath than when inhaled. Here is a complete settlement of the problem from a single fact, for the reverse must be true if oxygen is the source of the heat. The oxygen is not in its atomic form when exhaled, but is in the water vapor or combined with other elements, and especially in carbonic acid.

Fourth, carbonic acid is found in the expired breath, and this gas has two parts of oxygen to one of carbon. But the real principle, and the real force in the argument is not on the surface here and will be missed by many readers if not mentioned. There would need to be such an exact regularity and uniformity of these varying elements to keep the unfailing temperature of 98.5° that cannot for a moment be admitted as possible from our knowledge of chemistry, for we must not forget the law, that it requires the exact conditions to secure the same result. Even were it possible to figure out that the oxygen could thus generate heat, the fluctuation of quantity would be sufficient to dismiss the probability. The uniformity of the quantity of oxygen in the air has been sufficient to conceal the lack of uniformity in the other conditions. What a wide variation in the heat from fuels from cumbustion. Every kind of wood and variety of coal supplies differing amounts, and the same differs with its condition. Therefore the same must be true from foods, and that this is true is not only known by the scientists and physicians, but is of common knowledge and every one knows the difference, from experience, in the richness of foods. And we shall presently see that the regularity of breathing is now considered as being controlled by the quantity of carbonic acid in the blood, and which the above reasoning completely annuls.

We breathe faster when exercising and therefore inhale often twice to four or more times the usual quantity of oxygen, and yet the temperature of the blood remains practically the same, and the test is made nearest to the lungs where the heat is "generated" as now considered, but as the New will later claim as being collected. The most common simile used for the

lungs likens them to a furnace, and yet the principles will not hold. If the furnace is given sufficient fuel it will melt itself down, or destroy its efficiency. Now the fuel for the lungs is exhaustless, and the more violently we exercise the faster we breathe, or crowding the furnace, and the blood not only does not increase in temperature, but the rapid breathing is one-half of the provision for keeping the temperature down, a diametrically opposite effect of the furnace. Just consider a panting dog in sultry summer. According to the "oxygen theory," from the principles of the furnace and because his mechanism has more combustible material, he should "take fire," or at least destroy the mechanism. But instead, we find that his rapid breathing furnishes pleasurable relief.

In the sixth place it is logical to doubt the regularity of the passage of the oxygen from the air into the lungs, and of carbonic acid from the lungs, as the "theory" requires ("theory" is for the purpose of emphasis). The illustration, or experimental proof, however, is very convincing, and seemingly quite conclusive, which is as follows: A bladder of venous or as it is termed, impure blood (but it is really not impure but merely impoverished as we shall see) in a jar of oxygen. In a few hours the dark red blood will be a bright red, and CO_2, carbonic acid will be found in the oxygen gas. Now the change in color is perfectly understood from the new explanation of the cause of the color of objects as given in the subject of light, and it also proves that the blood is impoverished rather than impure. The principle in this interchange of elements is known as gaseous diffusion, and when the change takes place between liquids (a liquid in place of the oxygen gas) the passage of the elements in and

out of the bladder is known as endosmosis and exosmosis. These were puzzling facts until I chanced to make the acquaintance of Rx and his attendant principles, and it can be quite sufficiently elucidated in a sentence: It is the varying affinity between rex and atoms, as individual atoms, and also between molecules, and it is this affinity that tears down one set of molecules and combines others, the vital principles by which the blood, one of the most prominent factors in our discussion, is manufactured by the digestive apparatus, and fitted and refitted for its great offices by the lungs. With such evidence it is little wonder that it was decided that oxygen furnished the heat. (The reader must bear in mind that I am not discussing the office of oxygen in the system, but merely the fact of what is the heat of the body, which is determined by temperature, and that it is not combustion, as now understood.) It must be noted that the experiment has a quantity of pure oxygen, and yet considerable time is required for the change. The air is only one-fifth oxygen and it is combined with four parts of nitrogen. Now if the bladder is suspended in air this result will not be obtained, why then should we expect the change in the lungs to be similar to that from the jar of pure oxygen? Then the change in the lungs must be far more rapid under the adverse conditions. The change in the color, which is only one of the signs of the change of consistency, leads into the deepest scientific understanding of atomic and molecular principles, involving chemistry, physiology and physical considerations.

The pressure of force and the flow of heat is outward from the heart and veins, the principles that govern in perspiration, which must take place even more from the inner surface of the air cells of the lungs, and

which is the cause of there being more oxygen in the exhaled than the inhaled breath. Therefore, the most logical conclusion is that the carbonic acid is formed in the air cells than it's being generated in the blood and forced into the air cells, for it should be forced from the whole surface of the body as well. Carbon is forced into the lung cells and uniting there with oxygen in the air, forms the CO_2. The cilia (inner velvety lining of the cells to be more fully noted) are more conducive to evaporation than a smooth surface. This too is a different kind of partition between the air and the blood in the veins, than the bladder in the experiment noted above, and so great as to render most improbable that diffusion would be the same.

An eighth consideration relates to the impurity of venous blood. I used to teach, just as I learned it from the Professors, that the venous blood returning to the heart after a circuit of the body, was dark and just loaded down with impurities, while now I do not believe that such is the case. I will combine the ninth item with the eighth, for the great purifiers of the blood are the kidneys. The blood has built up and maintains the channels and material region and mechanism through which it passes. It does not use any "old kind" of material that happens to get into its channels, but selects the exact and best, and that is why every part serves its purpose so sublimely. In its constructive era or growth, with a higher tide and swifter current it goes out loaded with constructive material, and it returns impoverished of this material which partly lowered its ruddy color. Partly, remember. It goes out again enriched and renewed in color. But in the next era manhood, when the construction work is all completed, it returns less impoverished but the same in color. Ah!

Then it could not have been the loss of material that made the change in color. Now oxygen is largely used in building the tissues and is found in water, even in the bones. Now since there is more oxygen in the expired than the inhaled air, the source of the supply must come from the food and drink, and since all the other elements required by the body come from this source the only logical conclusion, and especially after the evidence already deduced is, that the oxygen does not come from the air.

What I mean is that the oxygen does not come from the air in the quantity required and for the purpose claimed. There may be some oxygen absorbed from the air by the lungs, and there may be a much larger per cent than is now claimed and not affect my contention regarding the heat and the manner in which the supply is obtained and regulated. I have given a new explanation of Heat, and to make that explanation conclusive I must demonstrate that it meets, and meets more perfectly every phase and phenomena of heat. And here is one of the most trying tests that can be found. Now my demonstration will be more forceful when I show that the present explanation is defective in every application, because, as I stated in the beginning, there cannot be two correct physical explanations for one and the same thing.

Oxygen is rarely found pure and alone in nature, save in the blood and possibly one exception, which, however, is transitory and readily understood by the new order of things. This case is ozone, which is oxygen separated by lightning and so charge with Rx that in the atmospheric gas it cannot come in contact with other atomic elements. Its artificial preparation confirms the same. It has been noted how difficult it is to

artificially separate the oxygen from the hydrogen in water, but we must understand that nature has no difficulty in breaking this union. It only requires an atom with a little stronger affinity and the bond of H_2O is "broken," but another is instantly made, hence the difficulty, that I mentioned, of catching oxygen, or hydrogen, for that matter alone. This is what makes water such a great solvent:

THE PRINCIPLES OF ATOMIC AFFINITIES AND THE REPULSION OF RX THE SUBLIME DIVERSITY AND SYMMETRY IN THE MULTIPLIED FORMS OF NATURE.

Therefore, let no one get the impression that I think, or am trying to prove that the oxygen is of less importance in the system, or in Nature than now claimed, for it is quite as essential in supplying heat to the body, as is now claimed, but in a completely new manner or office, and because of the new principles, and which are presently to be fully and definitely explained and demonstrated.

Another strong consideration is the fact that the kidneys are the principal purifiers of the blood. The arteries that carry the blood to these organs are entirely too large for simply supplying them with nourishment. Their sole purpose seems to be to look after the liquidity of the blood by which they take care of the excretions, rejecting those elements that have not been built into blood corpuscles, and it is the size of these that retains them in circulation. The claim now is that there are free oxygen atoms in the blood, and it is a mystery to me why they are not rejected by the kidneys, for water molecules which are much larger pass out freely. Yet the test of oxygen in the blood seems accurate. But it is made to appear that the lungs have a

similar purpose, for the blood is passed through the lungs far more frequently than through the kidneys, but some excretion does not pass from them just as from the surface of the body.

But a tenth and still stronger argument against the "motion theory" is the fact that the only noticeable and effective change of temperature of the body is from disease. The first symptom of the sick is a rise in temperature, and in some cases less oxygen is taken into the lungs, and in the case of pneumonia oxygen cannot readily pass into the lungs, and yet then is the time when the body has the greatest heat. Does this not settle the question that we must look for some other source of the heat of the body, and as well "some other kind" of Heat?

But as an argument for my contention, how can the theory find an explanation of the fact of the temperature often in a diseased hand or foot being higher than any other part of the body? The blood has been cooled on its journey from the lungs, and yet at these extremities it is heated above that in the furnace of the body, the lungs. It may be answered by the potency of hypotheses.

In these ten general arguments there are many minor ones, but this last consideration is alone quite sufficient to carry my claim that the lungs serve another purpose than that now understood. The facts that often a single shock in the lungs is fatal, and that they lose their power so quickly from so many other gases, require a new understanding.

The lungs are not now considered as the source of nervous force, but that they are organs operated by the nervous force for the purpose of getting a supply of oxygen into the blood for the generation of heat on the

principle of combustion. The fact that four-fifths or a greater amount of the chemical combustion in the preparation of the blood takes place in the stomach and intestines (which is an omitted argument) should have long ago taught us that there must be another purpose in respiration.

Finally—All that I have given relates to the conception when I studied physiology, but some progress has been made, or at least, a great modification of the conception of the heat of the body has taken place, which alone should give all I have brought forward full argumentative weight. It will be seen that the notion of heat generation that I have been combatting is a little off color in the eye of present science. This is due to the development of the idea of *energy,* in an attempt to make it agree with the notion of "motion" as energy, and traceable to the "motion theory of heat," which, although disproven so many times, must be again noted for its intrusion. The points that I have noted are now the most general belief. But I have a late normal and pathological text on Physiology for students and practitioners, and note a remarkable change in the treatment of the "pneumogastric nerve." It is not given in the Contents or Vocabulary, and Vagus, the name under which it is now treated, is not in the text books that I studied. This will be treated a little farther on. For the benefit of the student it is necessary to define some terms that it will be necessary to use in the showing that the new conceptions and treatment does not meet the situation any more than the older, yet it furnishes some strong confirmation for my contentions.

Chemical affinity has already been set forth as a chemical process in which the varying affinity of atoms

for Rx results in a solution of tearing down some kinds of molecules and building others. Now when these processes take place in animal tissue, the chemistry of the body, it is known under the name of *Metabolism,* and the two results are, *Katabolism,* and *Anabolism,* the former is the tearing down of molecules, as the digestion of food, and the building of blood corpuscles and the increase of flesh is the process of anabolism. Animal tissue is now considered as built up of cells which contain protoplasm or the living substance. There are parts and divisions of the protoplasm, but it is not necessary to go further into the subject than to understand that science has located the impulse of life as springing from the protoplasm of the cell.

But there is virtually no change in the notion that the heat of the body is the result of combustion, but it is not confined so closely to the lungs and the blood. It is now stated as the liberation of *Energy,* which we have found to be a very comprehensive term, and therefore very convenient. Then it is stated in the new form as "the liberated heat of metabolism," which, as above, is chemical affinity which is combustion, and we are at the point of beginning. The difference, however, is that from 75 to 80 per cent is considered as being liberated in the muscles. THIS IS THE NEW FEATURE THAT IS SO HELPFUL TO THE NEW CONCEPTIONS.

To make sure of my position I should take up these new conceptions in some such manner as that for oxygen, but do not feel that it is needed. For much of the former arguments apply equally here.

Nothing has been gained for the present conception by having 80 per cent liberated in the muscles, for by the principles of the present notion of the law of the "Conservation of Energy," it was the equivalent of that

much heat somewhere in the body, and it has to be shown where and how this "energy" got into the body. And I do not wish to conceal the fact that science does make the law hold good according to the conception of energy, and I trust that no one has been unfortunate enough, nor has so misunderstood my position as to believe that my restrictions against present science implied that its philosophy is not consistent and logically and scientifically supported in every part, for that is the reverse of my meaning. I will therefore state directly that science has made its philosophy consistent, even in the subject of astronomy where there appeared more conflicts than in any other division, and that was directly due to the fact that astronomers have adhered to the general understanding of all branches of physics and have sought explanations along those lines, and too, have found them, but, requiring problems outside of the sphere of the Earth, enlarged the points of differences. It is such a serious point for me that I will describe the apparatus by which they determine the amount of heat generated or given off by an animal in consequence of the food it has taken, and also for testing the "potential energy," according to the present conception of that term, of the various foodstuffs.

The apparatus is called a Calorimeter, one form of which was explained in the chapter on Heat. This form determines the number of heat units or calories dissipated by a body, and derives its name from the calorie which is the heat required to raise 1 gram of water 1° C. The device consists of two air chambers covered with heat non-conductors, which are connected by a sagging glass tube half full of mercury, which is named the manometer balance, for if the air pressure varies the mercury will indicate in which the pressure

is greater. The animal is placed in one chamber, and in the other hydrogen is burned sufficient to keep the mercury balanced. Since the gram-calories of hydrogen are known the quantity burned will determine the quantity of gram calories given off by the body tested. Now by the calorimeter they determine the heat units in various foodstuffs, and in applying their tests in other experiments they have found that these hold true, and thus the law of the conservation of energy is proven accurate, in line with present philosophy. Therefore science in all of its departments is just as anxious to test its declarations as I am for the New Philosophy, and the evidence in every case is worked out as accurately as in the above. Now, is not the above conclusive? Can anyone accuse science of not being scientific and true to its principles? And this digression is to prove that I have not, nor have I intended to convey such an impression, but have stated that the fault of present philosophy is in erroneous fundamental factors against which it has all unknowingly had to contend, yet nevertheless has brought it into a fairly consistent whole.

Now, this illustration has surely set my intentions aright with not only the general reader, I trust, but the professional scientist. But I am not through with the calorimeter. For it supports my contentions as accurately as it seems to uphold present science. I wonder how many readers, scientists as well as others, see wherein the test is necessarily accurate, and in consequence should hold true everywhere and thus seemingly prove the present conception of the law of the conservation of energy, and yet does not prove that the conception is true? I include scientists thus definitely because they have had the most to do with the law. Now, I have propounded a problem, and those who

wish to work it out for the pleasure of working should not read further until they are ready to compare solutions. The gallon is a quantity established by law. If one buys a quantity of sirup by the gallon, it is measured to him in that way, and then he tests the measurement by the same measure, if he is in doubt. Hence he has no doubt when it is measured, for it is measured in the same number of cubic inches. Now in the calorimeter the measure was made by heat, of heat and therefore everywhere the result should return the same measurement, for there is no possibility of a mistake. This is not the whole answer.

The measurement of the sirup did not prove what sirup is, or that the measured sirup is the kind ordered. Neither does the calorimeter prove that heat is motion, or that motion is heat, or that the phenomena that are measured is energy or the result of energy. This is similar to the point I made in Gravitation, i. e., gravitation was used to test the kinds of matter to see if gravitation varied with the kinds of matter. But owing to fundamental errors coming down from the past has continually handicapped science, and hence it is that I do acknowledge the achievements of science, and say it has worked out a fairly well connected hypothetical philosophy in the face of defects in the foundation. Now the experiment is for the purpose of determining the quantity of heat according to the present theory of heat. The amount of heat from the burning hydrogen measured that liberated by the animal, and considered as all coming from the digested food. But by the new understanding we know that Rx was set free by the burning hydrogen, and that in addition to the heat from digestion that a large portion came from the air by way of the lungs, just as in a furnace. Science is

consistent, but the experiment is more forceful with the new conceptions.

This affords the final opportunity to make a final application, in the final proof of the accuracy or truth of The New Philosophy. The true Energy, which is the energy of the New, produces all the motion there is, but the motion is not energy but Force, Momentum, and which cannot produce motion, nor energy, and can only transfer motion. If more motion or any other force than momentum results from any motion it is due to the action of other energy than that which produced the motion. But energy does not always produce motion, for all cohesion is the force of energy and is without motion. Therefore Rx is the real agent in all the changes observed in the experiments.

This reveals the great contrast when the many quotations I have made are recalled, for the Old says that "matter possesses energy by being in motion," and that "capacity for doing work is energy," which is equivalent to saying that "motion is energy" for all motion has capacity for doing work. Hence here is one of the great handicaps that I have claimed science has had to surmount in its progress. "Inertia" is another, and "a single gravitational attraction," "Elasticity," "Density" or "Tenuity," and the great one, "The Ether." These had their influences in Heat, Light, Electricity, Magnetism and Gravitation. But the greatest handicap has been hypotheses, and directly traceable to the notion of "Inertia," so that now all phenomena rest for their explanation on hypotheses. While it is true that they do hold fairly well, it must be understood that they have been worked over until they meet the cases as nearly as possible, and at present a large number of situations are left open or tentative, with the hope that future

developments or hypotheses may be found to meet the cases.

Only a small portion of the above is foreign to the main subject in hand, for the latest physiology claims that 80 per cent of the heat energy of the body is liberated in the muscles, and although some is set free while the muscles are at rest, the greater quantity is produced by their motion. They, however, lose their heat producing function if they are paralyzed by curare, and become the same as cold-blooded animals. We will find these new developments very useful in demonstrating the contention of this chapter. The appearance of heat in the muscles lends strong support for the motion theory of heat, for it is the ubiquity of motion that has so maintained the theory. But all of the discussions of motion disprove this origin of the heat of the body as completely as have the above considerations eliminated oxygen as the real source.

With a final case that neither oxygen nor "liberated heat energy" can take care of, the new explanation will be stated. These cannot account for the lungs not only not freezing when passing from a room with air at 90° into a winter day with the mercury 40° below zero, but maintaining the temperature of the blood at 98°. And this is by no means an extreme case, for explorers in the Arctic regions, with insufficient food for days breathe air 60° and 80° below zero. The law of Cause and Effect excludes both of the present conceptions from an explanation. The variation in the quantity of air taken into the lungs is very slight compared with the extreme test. The fact of impoverished blood from hunger greatly diminishes the possible supply in accord with the theories.

Then next to this test is the capacity to stand extreme temperatures, for from 104° to 108° often prove fatal, and the maximum known 112° was fatal. Then workers in foundries and glass works often remain for hours in a heat far above these temperatures. It is recorded that a man remained ten minutes in a dry bath at a temperature of 284°, and others for a shorter time in greater heat. Allowing for all the other means by which the temperature of the body is maintained at normal heat, some other kind of heat and a different understanding of its generation and distribution must be secured to account readily for the uniform temperature of 98.5° and at the same time readily take care of these extreme cases.

Nearly the whole of my manuscript is in type, yet in closing I desire to present some experimental proof that my declaration, that oxygen is not the source of the heat of the body, is correct. For in the following quotation from Dr. Leonard Keene Hirschberg, A. M., of Johns Hopkins University, it will be seen that both plants and animals live and thrive without any oxygen whatever:

"It now is admitted, if not confessed, by several western astronomers that the moon, in spite of its lack of atmospheric oxygen, undoubtedly sustains life. With the rapidly accumulating evidence that life may exist, thrive, and spread over our globe, independent of all ordinarily breathed gases, astronomers are forced to the conclusion that life is just as reasonably possible on the moon as on Mars or the earth. The proof of this is brought to light in the knowledge that many earthly plants and lower organisms multiply luxuriously *when all oxygen is kept away from them.* The number of species of animals and plants capable of so doing is open to unlimited increase, for by gradually changing the environment from that of oxygen to that of nitrogen, these creatures become adapted to a radically different atmosphere. So far it has not been possible for the human family to do this."

It is not therefore self-evident, that had I this evidence in the commencement, that none of my numerous arguments against the "oxygen theory" would have been needed to support my contention that Rx is the real source of the heat of the body, and that oxygen only plays its part with the other elements in securing Rx for this purpose. But I would not put oxygen on a par with other elements for it has a special fitness for this purpose, and I will be free to state that I do not believe that any other gas can permanently take its place, notwithstanding the experiments.

This also strengthens my contention that Rx is the life of every gas, and that it is associated with every kind of matter, while no other element is so ubiquitous. All of the arguments are therefore proven accurate and should have additional weight as arguments.

This affords the opportunity for predicting that, if there are any points in this work not sufficiently supported by arguments for the reader to consider them substantiated, that sooner or later experimental proof will be found to establish them as in the case of the oxygen.

The *New Philosophy* brings forth Rx as the Heat and Nervous Force of animal life.

RX IS HEAT; CURRENTS OF RX ARE ELECTRICITY; RX IS THE SUSTAINING FORCE OF THE ATMOSPHERE; THE LUNGS ARE THE DYNAMO OF THE BODY and, COLLECTING RX FROM THE AIR, THEY CREATE THE ELECTRICAL CURRENTS THAT SUPPLY THE HEAT AND NERVOUS FORCE OF ANIMAL LIFE.

The lungs are automatic and supply first the currents of electricity, and now considered as nervous force, for their own mechanism, and then as heat and nervous force supply the system as demand is made for them.

The design of this Chapter is to prove that Electricity is the Nervous Force of animal life, and since I started to do this by proving that the present theories of Heat could not reasonably account for the heat, and that Rx is the heat of the body as well as all the heat we have investigated, it is best to conclude this subject while it is in hand, and before proceeding to the fuller confirmation.

It was easy and logical to adapt the "motion theory" of heat to the generation of animal heat, and it seemed so logical and scientific that the theory of the heat of the body has strengthened the theory of heat, which supports my contention above, that science has made strenuous efforts to prove the steps of its progress.

Now combustion as commonly understood produces heat and the body seems to generate its heat by combustion in the lungs and stomach, but above I have restricted the production of heat to the lungs. But we forget that only comparatively few chemical processes develop heat, while the majority of them require heat, and as we now see, a flow of Rx which is the same thing, for the processes to continue to a definite end. The principal chemical processes of nature do not develop heat but require free Rx for their continuation. Really the evidence shows that the same is true of digestion as in vegetable growth, for the temperature of the stomach is not raised by the chemical action but from muscular action and from the excess of blood that flows to that organ when it is in action. If this were not so there would be a greater variation in the temperatures from the different kinds of food eaten.

In most cases the chemist employs heat to effect chemical action, and the real cause for the need of heat

is revealed for the first time by the new philosophy, for Rx is not only the heat but it is the one element that takes part in every chemical action, since it is the repulsion and cohesion of all atomic and molecular actions. Therefore, how far astray was I when I pictured to my class in physiology that the stomach and lungs were the furnaces of the human anatomy, and using the quotation given in the subject of heat confirming the "motion theory" showed how motion was stored in the summer by vegetation to be released in winter by digestion. But we have found that Rx a material thing is stored and not abstract motion.

Therefore Rx is collected by the lungs and on the principle of electrical heaters supplies heat for digestion in the stomach and reinvigorating and heating the blood in the lungs, and every consideration is so commonly evident that it will not be necessary for me to take in order the restrictions given against "oxygen" and "motion," and show that the new explanation meets the requirements perfectly, but it will be pleasant to point out some of them.

About the most important is the uniform temperature of 98.5°. This is readily accounted for by the facts of the UNIFORMITY of the one essential element, the atmosphere, throughout the Earth, and the SIZE of the nerves, and these two facts supply answers to nearly all the phenomena of the heat and nervous force of anatomy. Those acquainted with the practical application of electricity will readily see the great importance in the fact of the size of the nerves, for the currents are regulated by the size of the conductors. The size of the nerves are proportioned to the size of the parts they serve. The electrical tension of the lungs is set at that of the uniform temperature of the body, and the aura of the body

is one of the ways by which the tension is regulated, and to take care of excessive heat it results in visible perspiration.

The vital relation of the lungs to life is at once evident, for electricity vanishes with the breaking of the current, and the breaking of the current of the lungs destroys all the other currents. Paralysis is the breaking of some currents, but the breaking of this one in the lungs is the stopping of the dynamo, and life flies away.

But one of the most satisfactory and convincing solutions is that for taking care of extreme temperatures in the air. The quantity of Rx determines the tension and the flow of the current and the lungs collect directly from the air. The colder the air the lower the tension and the more rapid collection of Rx, which is heat, right at the source, hence it does not depend on the amount of O, or CO_2 in the blood, nor does it have to be generated under such unreasonable extremes and hastened to the surface of the air-cells to prevent freezing. For this test is as conclusive as can be found against the molecular motion theory of heat, because the lungs can keep the temperature of the blood at 98.5° indefinitely using air 125° colder, with any of a great variety of foods, and under quite the same conditions keep the same temperature, with air only 8° or 10° colder. Present physics or chemistry does not take up this problem while it is a logical consequence of the New Philosophy.

Although the evidence is not completed, I feel that my promises have been met that a higher use of the New Atmosphere, and the New Electricity would be proven than any given in those chapters. At least I shall not worry over unfulfilled promises. The

evidence, however, will be cumulative from now to the close.

It will not be necessary to secure a general understanding of the anatomy of the Nervous System, the apparatus that collects, uses and controls the electricity as the nervous force of the system.

THE NERVOUS SYSTEM

This is not to be considered as a scientific physiological treatise, but merely giving the general facts and principles that should be of common knowledge, and because of its close and logical connection can readily be remembered. I will use this connection largely as a guide in treating the subject, making the applications as we proceed, instead of following the order of the physiologist.

In the chapter on Electricity we found that in the generation and use of electrical currents materials had to be selected with reference to their conductivity, cohesion, and attraction affinities, using the poorest conductors (for all matter is a conductor) as insulators. We will find that these principles hold in the Nervous System, and that the body possesses a perfect Electrical Plant.

The vital processes of digestion, circulation, absorption, and respiration of all animal life are dependent upon a nervous system. These processes are known as vegetative because they are common both in vegetable and animal life, and hence it will be necessary to distinguish between them. In the very lowest order of animal life the system is so simple that it is difficult to distinguish between the vegetable and the animal, and here it can hardly be termed a system. For example, the fresh-water polyps seem to have no specialized

organs, for if severed into many parts, each will develop into a complete hydra. Ascending from the hydra in the scale of animal life, the organs multiply and the functions become more individual, and the whole becomes more and more complex, yet complete in each division until the highest, the most complex, and limit in animal life is attained in man. This progression more than any one other single factor has fostered that evolution which considers matter as its own designer and potentiality, the beginning and ultimate of all, in other words, atheistic progress or evolution. And also of a theistic evolution which is now more common and better, but which still mars by the taint of its humanism. The former sees man as a batrachian climax of mingling matter, and the latter, as a creative process to the same end. This much serves the purpose, but it is hard not to refrain from an extended argument, of pointing out that all of the various divisions are in themselves complete individuals. The nervous systems are complete and serve completed mechanism. The mechanisms are complete and are for their special purposes. The terms dust, clod and gross matter have had a tendency to imagine an ethereal matter, while all matter is divine. What ethereal matter could we wish sublimer than Rx that daily visits us with such lavish gifts of gravitational force, and Heat and Light and nightly on tireless wings whispers to us messages from the distant realm of our possessions? This tangible view so completely relieves the necessity of a universal ether, that the conviction of its existence should be easily dismissed.

It is this very matter that builds up and controls the Nervous System, that we are now studying, the sublimest aggregation of princely matters that can be

imagined, and it is through their own potentiality by which we are enabled to fathom their imperial functions. We forget that the soot that soils our fingers and occasions the frown, can become the diamond that sparkles on a more marvelous throat, and that the human eye is more marvelous than any gem in all the vast realms of Orion.

The nerve system is composed of two distinct kinds of matter, a gray cellular substance gathered in clusters called gangleon (knot) in protected portions of the body, and a smaller quantity of silvery white fibers, like fine silvery wires branching from the ganglia and ramifying every portion of the body. These are the wires that on the principles of electricity deliver Rx to all parts of the system, and then Rx performs just those functions of which we have already found him capable. And it is quite remarkable that we do not need to assume any new functions until we are ready to turn the mental mechanism over to Dr. Metaphysician, into whose domain it is not safe for the physicist to enter.

THE LUNGS

The real functions of the lungs are three: First, the source and supply of all the Nervous Force of the body, which they collect and create as Electricity through the agency of the atmosphere; Second, they maintain a constant electrical flow and tension in the system; Third, they reinvigorate the venous blood by a continuous supplying of Rx, or in other words, keep the blood in the lungs at an even temperature.

The lungs have been considered as the collectors of oxygen from the air for the purpose of chemical action, or combustion, and of course that is very near the truth

(I mean adjacent to) because oxygen as has been shown carries a large quantity of Rx. The blood is made up of a number of kinds of matter and oxygen is only one of the abundant kinds, and its proportion is as accurate in amount as any other in pure blood, and it is the excess or minus quantity of any element, as well as injurious elements, that makes the blood impure which finally results in causing some kind of disease, or making the system susceptible to disease.

The old idea taught when I was a student was that all of the heat of the body was generated in the lungs, and that it was distributed by the blood to all parts of the body, but this has been wisely corrected by later investigation, and as I have quoted something over 75 per cent is now claimed as originating in the muscles, and the per cent is not far out of the way looked at only logically, for while the lungs keep the blood in them at an even temperature, for all of the Rx supplied there, does not have any heat effect, but enters into the perfection, or building of the blood into an exact condition, which may be termed a growth. To make it still clearer, new blood material, partly built enters the lungs for the first time from the digestive organs, and here in the lungs by their heat, which is excess Rx, it is perfected. When a person goes without food, or is starving, the affinity of the body is weaker than the blood which begins to tear down the flesh (katabolism) and when this material reaches the lungs it has to be perfected as was the new material. This is why one grows thin from insufficient nourishing food.

There are two lungs, independent of each other, located in the right and left chest, which with the heart, they fill. They have a double covering called the

pleura, the inner one being attached to the lungs and the outer covering to the walls of the chest. These are exceedingly delicate and smooth membranes, supplying their own lubrication, as they slide over each other in the actions of breathing. The lung-substance is like a sponge, soft and elastic, crackles under the touch of the fingers, and called crepitation when detected by the ear with a stethoscope, and is due to the air in the minute air-cells which are the terminations of bronchial tubes, which, like branches of a tree, increase in size from one twenty-fifth of an inch, uniting into larger branches, finally terminating in a large tube in each lung which uniting form the trachea, or wind-pipe, by which the air enters and is expelled from the cells.

The walls of the air-cells are very thin and are covered with the most delicate capillary network in the body. The tubes are reinforced by bands of cartilage which while allowing them to bend slightly, prevents them from collapsing with the expulsion of the breath. The trachea is enlarged at the top into a box of cartilage named the larynx across which the vocal cords are stretched, and still above which is the epiglottis, or door of the trachea. The act of swallowing closes the door, while food and drink are passing into the esophagus, for the trachea draws a strict line at gases, and there is "something doing," when liquids or food slips past this door. Here is a safeguard that it would take many eons for one kind of evolution mentioned to account for before it could commence to explain away thousands of others. In short, matter would have to do considerable thinking, and thought was not a possibility until this "door" and its attendant mechanism was completed.

THE CILIA

We have now reached the parts directly concerned and connected with the nervous system. What has been described are the accessories and scaffolding, the framework that makes the purpose of the dynamo possible. The inner lining of the air-cells and air passages are lined with a moist mucous membrane composed of a peculiar kind of cell, which indicates their importance and special mission, but the most striking feature is that the surface exposed to the direct contact of the air is a velvety covering termed the *cilia,* or *ciliary-process,* a delicate hair-like covering, constantly waving in an outward direction, and the physiologists have concluded that their chief office is to expel foreign material from the lungs. The cilia motion is in unison and move like a wave produced by a breeze over a field of grain. This might be their chief office were it not for the fact that all cells are more or less profusely provided with a ciliary process, and that motion, and similar motion, is common to all. Therefore this is only a secondary office, or an essential factor is made to also safeguard the system. The essential of breath is the preservation of life, but it also serves as the same time the office of speech by means of the vocal cords. But in neither case are they merely accidental but results of a single design.

Therefore the first motion to be observed is that resembling on electrical impulse, and that is just what it is, and quite sufficiently demonstrated by the facts already established. But a conclusive evidence is in the fact that the motion carries force far above their momentum. In the case of a frog's esophagus the velvety cilia will carry 1.54 grains of lead up an incline

of 60°, and in the case of some animalculæ the ciliary motion can propel the body over smooth surfaces. The rigidity of this movement is caused by the varying tension of Rx in its electrical capacity.

But there is a still more important fact connected with this inner lining of the air passages. I have had occasion to impress the fact that Rx is on the surface of all objects, and the smoother the surface generally the larger the quantity, and the greater the resistance to impinging Rx. Now this is the principle of mirrors. This is what makes the surface of water such a good reflector. Hence it can be seen that were this lining a smooth coat of mucus, that the bombarding force of Rx in the air, and especially at night, could not force through this coat of mail. This is the reason daylight is so much more refreshing and invigorating than dark damp days. The Rx has a greater velocity, and consequently the full electrical tension of the lungs is more readily sustained. There can be no question that this is a forceful factor, because it requires the light velocity of Rx to break through the cornea of the eye. But here a cilium is like the point of a lightning rod inviting attack from the bombarding Rex of the air. The flow is inward over these cilia, and is regulated by the tension within. Were the flow outward here, as it is from the external surface of the body, their points would be repellent, and would not collect Rx from the air, and there would be an aura as from the body.

Now the cilia may collect Rx from the molecules of the air as well as from the free, or bombarding Rx. For not only the oxygen and nitrogen, but every element in the air is there by virtue of the quantity of Rx they can hold, and the most elusive are those that have

the strongest affinity, and as already observed, the great value of oxygen is its large capacity and weak affinity for Rx. Hence oxygen could give Rx to the cilia and form carbonic acid with the carbon thrown out by the cells.

But I wish to leave no doubt as to this action of the cilia and Rx, and to impress that I am not assuming the same, which would flavor too much of an hypothesis: Hence, we know that Rx is passing to and fro continually through all matter, with the ocular demonstration of light through glass. But in addition to this flow the affinity of the cilia, and the direction of the electrical flow inward, they collect an additional quantity.

THE NERVES

The nerves are the electrical conductors that ramify the whole system like the wires of an electrical plant spread through the city or district that is equipped to use the current. And like the wires they are everywhere insulated to the point they serve, and their structure compared to the material of the body compares accurately with the wires and the materials they traverse. They are composed of a dense silvery nerve fiber, and their insulation is affected by an encasement of hardened fibrous tissue throughout their whole course, which is an unbroken course from the part they serve to where they receive their nervous or electrical impulse. They are therefore not concerned in the production, but solely in the delivery of the force they display.

As a double argument that the force is electricity and the heat of the body, I wish to call especial attention to their minuteness, for they are only about 1/6,000

of an inch in diameter, which indicates the smallness of the quantity of electricity they can carry, and therefore I must show that this is an essential factor. There are two most obvious characteristics of nervous force. First the swiftness of its action, and second its power. The first is admitted without argument that electrical impulses meet perfectly the fitness. For the second it is only necessary to review a single fact, namely, the force of an inch square steel rod supporting 64,000 pounds which is the cohesive strength of an inch square single layer of Rx and steel atoms or molecules, for it is the cohesive action of Rx in the muscles that produces muscular force. Of course the steel rod is a special case, but the same holds true with muscles, for they vary according to their condition. Hence it is not a difficult problem to understand how man can lightly and with seemingly no effort easily, gracefully and continuously throw his 150 pounds around for many hours in a day. This powerful electrical energy is being as continuously collected by the lungs and diverted to the muscles, just like Rx is extracted from the coal and through the stream is applied to the engine, and stored in momentum or electrical currents.

As further indicating that the nerves are merely conductors of the nervous force, all of them may be destroyed, or lose their functions, with a single exception of one pair, without immediately destroying life, but of course, they would in time. This single pair is reserved for special treatment when we are in possession of all the other essential factors.

THE MAGNETIC CAUSE

I am convinced that the whole nerve is magnetic, or that there is a magnetic section near their source. For

a magnetic section would insure the current always taking the same course, which is the sole distinction between conductors of electrical impulses. For if one will notice some sensation follows every voluntary motion, and every such motion is the result of a motor impulse, and it is true of involuntary motions. This indicates that a portion of the electrical force sent out returns over the sensory nerve. In an electrical lamp, either arc or incandescent, only a portion of the current, and a very small portion too, is consumed in the production of the light. If this were not true electricity would be an extravagant luxury. A portion of the motor impulse is converted into heat, and this is why the physiologists have determined such a large per cent of the heat of the body is generated in the muscles. Is this not identical with the production of heat in the arc and incandescent light, which is from electricity, without any question? There is only one kind of heat, Rx is heat, electrical currents are Rx, but are not heat until some of it is converted into heat action; bodily heat results from current action, therefore the current must be electrical. Now the reason the excess motor impulse does not return over the motor nerve, is because the direction is magnetic, which is merely established direction of current.

NERVE CENTERS—THE BRAIN

Tracing any nerve from its termination on the surface of the body or in a muscle it will always be found to end in another kind of nervous matter collected in masses. This is known as the gray cellular tissue, and the two largest masses constitute the brain, securely protected in the rigid bony box of the skull, which, together with the organs of special sensation, they

completely fill. This matter is also found in the spinal cord and in ganglia along the spinal column, and altogether constitutes about an equal quantity of the fibrous tissue.

I will first treat the two kinds as gray and white matter, or cellular and fibrous tissue, by which the main purpose can be obtained, and will then look more closely into the tissues, that may lead to some even more surprising results.

The whole human system is practically two systems, working in unison, and yet in most cases each can indefinitely survive without the other, and were it not for the central source, they could be wholly independent. There is, however, one heart and one nerve that serves both on which each are completely dependent. And to meet this duality the nervous matters are divided into two parts.

The brain consists of two distinct parts, the *cerebrum* and the *cerebellum,* and each is divided into right and left hemispheres, and are oval, or egg-shaped. They constitute the largest collection of nervous matter, and in the adult weigh between 48 and 55 ounces, or about one-fortieth of the weight of the body. A brain deficient in weight or too large is incapable of rightly caring for the physical and mental requirements of the individual, which are evidences of the electrical character of nervous energy. The white tissue springing from these two divisions at their bases form the largest collection of this tissue and is known as the *medulla oblongata,* or spinal marrow, for from it springs the spinal cord, entering the cavity of the spinal column near this organ. The brain is soft and pliable and readily altered in shape, and therefore requires just such a housing as is provided by the skull. It is further

protected by three coverings, the *arachnoid,* or "spider web," the *dura mater* and the *pia mater* or the strong and the delicate coverings. These membranes furnish the needed supply of nourishing blood vessels. The supply of blood sent to the brain is all out of proportion to its relative size, for while it is only one-fortieth of the weight of the body the brain requires one-fifth of the blood of the system, and mental labor requires an extra flow of blood the same as the motions of any portion of the body. The weight of the human brain being heavier than all other animals, except the elephant and whale, indicates that it has an additional purpose above that of the mere animal.

THE CEREBRUM

The cerebrum is many times larger than the cerebellum, and occupies the entire rear, frontal and upper portions of the skull, and its right and left hemispheres are quite completely divided by a lengthwise fissure, connected merely by the white nerve fiber from each that forms the medulla. The matter has a ribbon or wide band formation, the white matter covered by the gray cellular tissue. These bands are arranged in folds, giving the surface the appearance of "convolutions," which they are called. They are about an inch in depth, with irregular windings, which arrangement permits of a large quantity of the gray matter. The estimated surface of these bands is four square feet. Since the extent of this surface marks the capacity of the individual, the great wisdom of the arrangement can be seen, for these furrows deepen in the convolutions as intelligence increases, and yet this method admits of securing such an increase in so small a compass and in such a symmetrical form. In children, before the mind

has been developed by mental exercise, these markings are scarcely discernible, and they appear and the furrows deepen as the individual increases in mental vigor. The brains of the less civilized are marked by the number and shallowness of these convolutions. The true source of nervous force is in the cerebrum and here it is due to the increase of the gray cellular tissue, and those are the most intelligent animals and capable of training that have the best developed cerebrum. Naturally the increase is in the gray matter, for the white is only the conductors, and increase of force is not the multiplying of nerves which remain the same in number like the bones and muscles. Then there is another important fact that confirms this increase. For if the development of the cerebrum is carried on without care of the physical force of the individual the nerves are not able to care for the mental and physical requirements, and the body suffers in strength, hence, the growth of the gray does not extend also to the white tissue.

THE CEREBELLUM

The cerebellum or "little brain" is situated below the posterior portion of the cerebrum, and just back of the line of the spinal column. It is similar in arrangement of its parts to the cerebrum, and differs only in having parallel ridges instead of the convolutions, or, in other words, the bands are parallel. This parallel arrangement gives a peculiar appearance to the white fiber in the center which resembles the trunk and branches of a tree, and in consequence has been named the *arbor vitae,* or "the tree of life." The gray matter extends down into the furrows as into the convolutions of the cerebrum. The cerebellum does not seem to take part in the operations of the mind, but presides

over the movements of the voluntary muscles, and it therefore is under the control of the cerebrum. A remarkable peculiarity of the brain matter is that it is devoid of feeling. It can be pinched and cut without causing pain, and portions of the cerebrum can be removed, and impaired by disease without affecting the mind or the movements of the body, provided, however, only one side is concerned.

I can here bring forward additional evidence to confirm the new declaration that the nerves are either magnetic throughout or have a magnetic division or connection. There I pointed out that there is necessarily a portion of the electrical motor impulse that is not used, and which returns a feeble sensory impulse, which, however, is recognized only by a special attention, due to habit, or its constancy. But in the cases of feebleness of muscular force or lameness the reflex sensory impulse is so pronounced that it causes pain, and then it is self-evident. We found that a magnetic substance is one where the atoms are so arranged that Rx is conducted through it always in the same direction, and that this is the difference between a magnetized and unmagnetized steel needle or wire. Since the motor and sensory nerves pursue the same course and are designed for different purposes, and since their terminations could not accomplish these purposes with the impulse flowing in either direction, it is scientific to look for a design that would insure a current always in the same direction. According to the present understanding we can only presume that the low potential is at the termination of the motor nerves, and that with continuous action it would still remain low, but if the direction is safeguarded by the nerves being magnetic, or having a magnetic control somewhere in the circuit,

the direction would be positive and be in accord with our knowledge of currents.

Now there are agencies, conditions and diseases of the nerves that indicate not only a loss of control of the current in the one direction, but that the direction is affected, although only slightly and intermittently. There are some forms of cerebellar ataxia that could be accounted for on the principle of the reversal of the current, and yet the strongest argument against the conclusion is that they can as readily be accounted for in other ways. The effect of intoxication which produces a reeling gait is not as indicative of this condition as asthenia, a cerebellar affection, which approaches paralysis. This would indicate that the potential at the motor terminals is quite equal to that throughout the circuit.

The nervous force or electricity of the body is quite a constant quantity, as indicated by constant temperature, and the conductivity of the nerves remains nearly as uniform, so that nervous trouble is largely due to lack of control because of the physical condition of the body, the parts upon which the force is applied. While the nervous force controls the mechanism and orderly functions of the body, if the physical conditions are not normal other things must be expected, and the result is disease. The nerves are the monitors and their warning is pain. The nervous force is therefore not a product of the body, as is the blood, which suffers so many variations, but it must be elemental, because only matter can affect matter (from our fundamental principles) ; hence the nervous force must be an elemental force that has no other variation than quantity, and only the electricity of the New Philosophy can meet this condition. The blood, the fluids and every individual

part of the body is composite and therefore subject to variations, and it is these variations that result in disease, in weak or robust bodies. The nervous force manipulates all of these and essentially it should be without variation in form, function or nature, and Rx meets this condition perfectly. It is the only part connected with the body that does not get out of order, and plays havoc with all parts when they become imperfect.

THE SYMPATHETIC NERVOUS SYSTEM

As still indicating the duality of the human individual, the body has two quite complete and distinct nervous systems. They are independent in action but co-ordinate with each other in their purposes. The sympathetic is dependent upon the one source of supply of Rx, but it looks after the physical functions and preserves the tone of the body, for its most efficient use by the greater nervous system.

The nerve centers of the sympathetic system consist of a double chain of ganglia, extending along each side of the spinal column, and other places in the cavities of the trunk, neck and head. These ganglia are connected by nerve fiber, and from them nerves ramify the parts in their vicinity. The two kinds of matter have a similar arrangement to those in the other system, and there is no difference in the kinds, which indicates that there is no difference in the force they control, and there is only one kind of electricity and that is Rx in currents.

It was originally understood that through this system the body was enabled as a whole to assist any afflicted portion; that if one eye was affected or injured the other would be affected sympathetically, and it was presumed that it would therefore the more readily

recover. Sympathy is such a commendable virtue that the name seems beautifully appropriate. It certainly is a very charitable way to look upon a condition, or a result that does the reverse, or "increases sorrow." For it really does not benefit the afflicted eye to have the well one get sick. It does not help one sick lung to have the other take the same or any other trouble. The only happy way to look at it is to conceive that the well eye is willing to be afflicted without benefiting the sick one. This is only a necessary consequence of a higher office of the union of the system.

The essential functions of the system and its union are the uniform and impartial distribution of nervous energy for the physical needs of all parts of the body; a wider distribution of storage; and third the maintenance of a safe electrical tension and tone in the whole system.

The storage (this is new but I must anticipate a little) for each of the special physical functions of the body is in this way located in or near the organs they serve, and are adjusted in size to meet the requirements. There is one central supply and they draw upon this as demand requires and not from each other. The wider distribution embraces all in its design; besides there are the special ones requiring a less quantity of nerve fiber, less liability of injury to the whole from disease or accident, and the danger from a large storage without the protection that is afforded to the brain, for a central storage would naturally require more gray matter than the aggregate of the ganglia, since they must be just adequate for their special organs.

Electrical tension precipitates a new factor and contingency, for nervous force has not been considered at all dangerous in the sense of an electrical current. The

design of the whole electrical system of the body discloses that such a contingency has been guarded against. Physiologists have recognized a portion of this contention and have expatiated upon the wisdom of the automatic movements of the heart, lungs, stomach, and the involuntary control the body acquires. As it is we know how frequent are fatal nervous shocks, and how much greater would be the danger were all the gray matter of the sympathetic system concentrated in a central storage. In the brain, which is the most securely protected of any organ in the body, the mental and physical apparatus are separate and distinct, save as to essential connections. The importance is further safeguarded by each being double in parts but with a single office. Then, since life is the most essential, the cerebellum and medulla oblongata are the most perfectly protected.

Hysteria is the result of a shock to a weak or deranged system, and it would be more serious and fatal in case of a central storage. A similar effect is noted in dynamos, and is known as hysreresis. There seems to be a dissipation of energy on the reversal of the current as a result of the induced magnetism in the iron fields, yet this is a portion of the load and is essential to a continuous current.

The causes of hysteria indicate electrical action in line with the behavior and effects of currents as was shown in the chapter on Electricity. The cause is mainly mental, and may be brought on solely from mental causes, and also by physical causes producing the mental. The first are occasioned by joy, grief, fright, or general mental excitement. These are concepts produced by mental concepts which is to say they are not occasioned from external contact,

material or electrical. Nearly every one is subject to having the appetite affected by joy and grief, and many very easily. Now these are affected through the sympathetic system, hence the system received its shock from the brain, which, however, did not affect the ganglia direct, but in a reflex manner from the effect on the muscles. Usually the condition of the muscular system has much to do with these effects. Therefore it is most obvious that the effects would be far more severe with a central storage of the ganglia.

The second cause of hysteria is first physical, resulting from accident or external contact, and although less frequent are proportionately more fatal. The electrical flash first reaches the medulla and cerebellum, and the greatest damage is usually done here, for we shall later see that the most fatal spot in the body is in the medulla. Usually temporary, and often permanent, paralysis results, because the cerebellum is the seat of muscular control. Virtually, from here a flash of nervous lightning is sent through the system, and there can be no doubt but that the effect would be far more fatal if the sympathetic gray matter was centralized.

"Nervous Prostration," what is it? It is the inability of the muscular system to normally control the nervous energy. For, as already stated, the supply of electricity is quite constant, and it must always have effects, and in normal health the supply is all turned to healthful purposes. This trouble occurs when the muscular system as a whole is affected, and quiet is necessary because activity increases the electrical supply and tension.

Now all that I have brought forward is for the purpose of demonstrating that every consideration is electrical in character and results in both systems, and that

it is the material electricity of the New, and not a special form of "wave" in an unknown and claimed "immaterial ether medium." It turns out to be then confirmation for the New Electricity.

STORAGE

There are two ways by which the several storages, which are the brain and the ganglia of the sympathetic system, may be supplied, namely, through the blood, and directly by the nerves, but probably by the former. The tension would be governed by the cells, which would act in a similar manner to the chemical cell. Through the vagus nerve the tension in the arteries and veins is maintained. In the cells the tension would not equal that of the medulla only when they were fully charged, and their exhaustion is what would weaken the medulla and demand sleep; then, owing to cessation of muscular action, the medulla and the cells are fully renewed. The process must be continuous, but during the activity of the waking hours the loss would exceed the gain.

Yet the supply can be secured direct through the sensory nerves and still be similar in action to the chemical cell. For in a metallic circuit the same Rx may pass many times through the electrolyte since it is connected with the zinc. This is proven by the fact that the current will not flow with a single wire or a broken circuit. At any rate the tension in the sensory is essential to the recouping of the cell from the other source, from the same fact of a single wire. The only point then that cannot be definitely settled is, whether the renewal comes through the blood or by way of the sensory nerve, or by both.

Each cell and a sensory and motor fiber that, with

whatever connection it may have with the other portions of the gray tissue, constitute a unit, and govern a single sensation and action, and that if others result they are due to reflex action through some nerve center. And there are usually other nervous events from each single cell action, and this is greatly increased when the initial action involves a large number of cells, as in the cases of walking, running or any violent exercise. Hence at the close of the day we find the whole body weary and ready for rest and sleep. In electrical parlance the batteries are "run down." Therefore the cells are batteries than can be renewed, hence the electricity is stored, for there is a tendency to flow just the same as in the wire or nerves, and that is electricity according to the new definition.

STORAGE OR GENERATION

The physiologists now hold the gray matter as the generator of nervous force, while I have located the supply in the lungs and hold that the gray cellular tissue is the storage of the supply. However, I could readily agree with them and secure quite as much proof that the nervous force is only another name for Electricity. For the cells of the gray matter can readily be conceived as galvanic cells as well as the cells of a storage battery. There is strong evidence for each contention, and it may also turn out that they are both generators and storage, but the facts as I see them certainly indicate storage.

In the first place in a perfect galvanic or chemical battery (cell), which this would undoubtedly be, electricity is generated only as it is used, as has been shown. Since each nerve draws only from its own special cell and not from a general supply, the quantity required and the constancy of the supply as determined from the

action, the size of the cell will not answer, unless we supplement a supply after the manner contemplated in the storage understanding. That is, we could not get the supply solely from chemical action. We could not figure out a "perfect electrical plant" as before declared.

The replenishing of the cells would present serious problems. While we must consider that the blood would look after the constancy of the chemicals in the cells, the constancy of the supply and the inconstancy of the blood would not agree, and in addition, rest alone will recoup the cells. Then the residuals of chemical action in the cells present serious problems that would not appear with the storage.

But when we come to consider the storage system there seems to be no serious problems whatever. The supply from the lungs is ample and for a far greater quantity than would be accounted for by chemical action. However, large as is this supply the cells do become exhausted, and they will be replenished by sleep even without food. And yet the exhaustion is not due to the lack of the supply but to the physical mechanism acted upon, and which may include the condition of the cells, their ability to store and give out electrical impulses. The tension of the system is doubtless what governs their ability to do this, and the tension is regulated by the lungs.

The need of storage is very evident, but is not equal to the evidence of storage. The demand for the current is very variable, even in both systems, depending upon physical exercise. We breathe faster and deeper when we exercise violently, which increases the quantity collected, but which does not go directly into use, but goes to the nerve center most requiring additional

Rx. In other words, it goes through the regular channels. And Rx is not carried direct to the centers electrically but through the blood as heat. This is why the heart beats faster, and why the nerve centers require such a large per cent of the blood of the body. It cannot be for nourishment, but is for this special purpose of keeping the storage supply at its proper tension, for exertion lowers the tension in the cells which induces the collection of Rx from the blood.

The demand for sleep is one of the strongest arguments for storage, for while food and all the conditions of supplying blood which furnishes the condition for the generation of electricity, or nervous force if preferred, are in full action, there is a demand for sleep that cannot be resisted, and which can only mean that the storage supply is exhausted, but not the supply for storage, that remains constant with the breathing. Shakespeare embalmed this scientific truth in flowery phrase when he said, "Sleep knits up the raveled sleeve of care." This is equivalent to saying that Sleep itself does not sleep, but knits up the sleeve while the mental energies are asleep. When the demand of the vast physical mechanism, which has been met through all the waking day, is withdrawn the depleted cells can renew their Rx or electrical tension. The supply from which they can draw must therefore be continuous and uniform, and that is what I have shown is possible, and only possible by way of the lungs, and there is no other element known except Rx that will meet so perfectly every condition.

An elaborate mechanism has been shown as the means of collecting Rx and converting it into electrical currents in a similar manner in which other electrical currents are produced, and in consequence of this collection

there should be a storage, just as the energy of food is garnered into flesh, and with only a brief examination it is seen that this storage is as complete and perfect as are the means of supply. If the gray matter generates the nervous force the only source from which it can obtain an element (for a force must be material), or whatever may be imagined as the nerve force, is from the blood, and we know that because of the inconstancy of its character and condition, this source is all too deficient to furnish such a uniform force in such exact and perfect quantities under all conditions.

The "New Atmosphere" was not worked out to meet the requirements of the Nervous Force of animal life, yet how perfectly they support one another, and of course this knowledge of nervous force could not have been worked out without the full understanding of Electricity. Up to this time nervous force has been merely a nonentity, and those who have considered it as electricity were no farther along, because electricity has been only a name for a special kind of actions between kinds of matter, and even those who have been able to conceive electricity as some kind of stress and strain in the Ether are no better off, because the Ether is admitted by every text published as unknown, and it is well, for nonentity cannot be known. Perhaps many have not thought of it thus, but one of the most prominent things of the New Philosophy is the materializing of Force as the action of tangible matter, for only matter can affect matter in physics.

Therefore the facts of the New Atmosphere and the deductions that Nervous Force must be a material thing requires that there should be some kind of storage, because its use is intermittent and irregular in amount,

and all of the nervous system we have noted indicates that the gray matter is the electrical storage.

There is still one other forceful electrical consideration: How quickly the incandescent or arc lights cease their shining when the current is broken! How soon is the vast power of the motor stilled when the trolley wheel is loosed! If one certain contact is broken in the silver threads that bind up and vitalize the human frame the wondrous power of a perfect motor is stilled, and the flame of life is flashed out in a divine mechanism perfect and seemingly immortal in every other particular, and the truth of Ecclesiastes is verified.

THE SENSE OF TOUCH

From the first we have had to deal with the presence of Rx on the surface of all objects. Electricity is here claimed to be the nervous force through which this sense sends its messages to the brain, and how useful then is this Rx on the surface. The currents of electricity are due to the repulsion of Rx. The tension of Rx on the surfaces of matter are just as varied as are the kinds of surfaces and the materials of which they are composed. Every sense admits of development, hence, what an opportunity here for cultivation of this sense? It is in evidence with every separate contact, and therefore unless special attention is given to it habit makes us indifferent to the general sensation. The blind are obliged to give it attention, and here we find it wondrously developed.

Some have been contending for a special sense of temperature, but having erroneous ideas of both heat and the nervous force they could not secure a correct understanding of the production of the sensation. But now with a new understanding of all these factors

another explanation of the sensation of temperature is at hand; and the fact that all the factors and results follow connectedly, and as essential consequences is flattering as well as scientific evidence that the fundamental principles are correct. Temperature determines the potential of Rx in different bodies, and the flow ss always from the high to the low. Hence when the hand touches a cold object the flow is from the hand into the object, which is warmed, for Rx is heat, and the hand experiences the sensation of cold. If the object is cold enough it will produce a blister in the hand. If the hand touches a hot object the sensation of heat is felt, and if the object is hot enough, a blister will likewise be the result. Looks like a paradox. But they are different blisters. A blister is an injurious adjustment of the molecules that prevents them from carrying on their function, and here are two ways by which the molecules are thus affected, and we know that Rx is the main factor in the construction of molecules, and for each a special quantity is essential. Here are two ways of destroying a normal flesh molecule, by adding or extracting too much Rx. We know that this is true, for Rx is heat, electricity and the nervous force of the body, and the exact conditions for securing these results are here present.

THE PNEUMOGASTRIC NERVE

In the pneumogastric nerve we have reached the climax of importance of the nerves of the body, according to the new understanding, for all the others are dependent upon it for their existence. When this nerve ceases to perform its office the play of all energy ceases, for it is accurately as well as poetically the silver cord of life. I presume for brevity, the physiologists now use the

name of the vagus for this nerve. It is suggestive if not accurately descriptive, because it wanders far.

It is the tenth pair of cranial nerves with additions from the medulla, and leaving the skull by way of the jugular foramina, it passes through the thorax to the lungs, heart, stomach, liver and spleen. Below the clavicle it divides into right and left pulmonary nerves, and in connection with the sympathetic system forms a posterior plexus with gray tissue for each lung. A motor trunk passes through the diaphragm and serves the digestive apparatus.

As earlier mentioned, I conceive that the sensory portion of this nerve originates in the cilia of the lungs and terminates in the gray matter of the medulla from which spring the motor fibers. Through the agency of reflex action, first assisted by the motor portion on the pneumogastric nerve, all the nerves of respiration are thrown into rhythmic action.

Thus in a general way all the apparatus of a physical electrical plant has been described, and we can now understand the last argument for storage. The vast importance and the marvelous use of the little gray tissue of the medulla can be seen. It is the primal storage of the body, embracing the two nervous systems, the cerebro-spinal and the sympathetic system. The gray matter of the medulla is the residual magnetism of a dynamo by which it is enabled to generate the full current. If the field magnets of a dynamo lose their magnetism, which is electrical potential, the current cannot be collected. When this gray storage is exhausted by an injury to the nerve near it the current is lost and indeed the "silver cord of life is broken." For this reason this little mass of storage tissue is known as "The Vital Knot." We speak of the small quantity

of this gray matter in the medulla, and do not realize that undoubtedly it is a much larger supply than is afforded any other nerve.

This storage is larger than needed for this one nerve, and in consequence by its tension it can for a greater portion of the time keep the other storages charged while all the nerves of the system are working at nearly maximum capacity. But in time the tension in all the storages becomes low and lowest, proportionately in the medulla storage, hence sleep is imperative, and sleep is a cessation of the voluntary activities which also increase all expenditures of nervous energy. An electrical storage battery cannot be instantly charged but is restricted to the rapidity of the chemical action of the chemicals employed. This is one of the strongest scientific evidences that the action of the cellular tissue is electrical. And a storage battery can be used while it is being recharged, but an exact comparison in this particular cannot be had because of a slight difference in the apparatus.

The compulsion, the absolute need of sleep is alone a most forceful, if not conclusive, evidence of storage, for sleep is the only way of relieving the whole nervous tension, and permitting the recouping first of the medulla storage. The argument for storage is not exhausted, but sufficient has been given.

How and Why We Breathe

Just how we breathe has longer been a perplexing scientific as well as common problem than why we breathe. Because breath and life come and go together they have become synonyms. The oldest texts on physiology tell us why we breathe, and give the same reason, to secure oxygen for combustion. But the recent have

gone farther and declared that we breathe because of trying to strike a balance between O and CO_2 in the blood, and because one or the other continually slips over we keep on trying, breathing. The older physiologists could not come thus near, and were content to think that the momentum of nervous force kept the mechanism going until it wore itself out, destroyed by disease, or silenced by external force. I will quote one as it is pleasant and forceful scientific fiction:

"Our brains are seventy-year clocks. The Angel of Life winds them once for all, then closes the case, and gives the key to the Angel of the Resurrection. Tic-tac! tic-tac! go the wheels of thought; our will cannot stop them; they cannot stop themselves; sleep cannot stop them; madness only makes them run faster; death alone can break into the case, and, seizing the ever-swinging pendulum, which we call the heart, silence at last the clicking of the terrible escapement we have carried so long beneath our wrinkled foreheads."—HOLMES's The Autocrat of the Breakfast Table.

I will first give the present explanation with an inspection of the same, and then deduce the explanation from the new developments.

The medulla oblongata is considered the center of respiratory action. When air is inhaled it is claimed that an impulse has been sent from the medulla to the muscles of inspiration, and that from the same source a similar impulse is directly sent to the muscles of expiration. This impulse is supposed to be nervous force, but bear in mind that they do not attempt to tell us what this force consists of, save that it is *energy,* and then define energy as motion, hence we must presume that it must have been motion of the medulla, but that does not relieve us, for it does not show what caused the medulla to move, and to move in an "energy way." Thus we have not gotten anywhere. But if pressed, present science would refer us to the blood (with the

same result), then to the food and air and so on, and the final result would be as the first.

But now it is claimed that the carbon dioxide in the blood stimulates the respiratory center to action; that the demand for oxygen is telegraphed to the medulla just as soon as the nerves of the blood vessels are irritated by the accumulation of carbonic acid and that the medulla replies by instantly flashing a sensory (afferent) impulse to the motor (efferent) nerves, and the stimulation from these nerves causes the inspiratory muscles to act. The trouble with this is that it does not locate where in the system the CO_2 is irritating the nerves; whether in the limbs, lungs, or medulla, or a general demand of the whole system. Let us presume the lungs (the objections would be the same); then the telegraphing would need to be over the sensory (afferent) nerves; hence the medulla would directly act upon the motor nerves, which I will give as a correction of the text, for otherwise, there would need be another set of sensory nerves.

(Completing a breath.) Presently the impulses from the visceral nerves evoke expiration, it is claimed, but does not state the action as it does for the inspiration, which precludes me from inquiring how the medulla can distinguish between "telegrams." But it makes it clear that the two "telegrams" come from different quarters, which is even a more serious dilemma. But the irritation that sends the impulse, it is claimed, is produced by the oxidation of the tissue, and that it is only when this reaches a certain degree or stage that inspiration recurs.

Only the scientifically posted are equipped to answer my restrictions against these explanations which are learned in the light of present known facts and under-

standings, but all can see the improbabilities, and can accurately compare them with the explanation that I shall give.

In the first place the agent (which positively must be material, for it acts upon matter) is out of sight, concealed under that convenient cloak "energy." The regularity, constancy and evenness of the motions of respiration cannot be accounted for by the action of two variable elements acting upon many kinds of other matter with variable conditions. I have shown this overwhelmingly so in the case of the single element oxygen, and the case is greatly weakened by the addition of carbon. The exactness and constancy of all known chemical actions, and all these are chemical effects, debar the possibility of these elements producing such exact uniformity. Everything is hypothetical between the places of action and the effects. This becomes more forceful when it is placed beside the explanation that will presently follow where there is no gap between the cause and effect, and no problem of time, which could be here advanced.

Above the declaration is that oxidation is essential, and that is now considered the source of heat, hence, it must be inferred that, if it is not heat that is telegraphed for, that heat generates the nerve force that is delivered. This only makes the problem worse, of breathing air 125° below the temperature of the lungs, and still generating nerve force, for oxidation requires certain temperatures.

The two sources for the impulses for inspiration and expiration can not be defended. As much argument as already given can be secured, but it is wholly unnecessary. The elemental action that I have noted is all-sufficient.

The truth is, that a cause was seen in the blood, an effect was noted in the medulla, and another effect was observed in the act of inspiration and the first effect was deduced as the cause of the second effect, with the general understanding that the nervous force, whatever it is (for no understanding of it is anywhere set forth) was the agent between these separated causes and effects by means of the nerves.

Nevertheless, with the limited and partly erroneous understandings, this is an erudite explanation of deep and mysterious phenomena. If I cannot give a better explanation my philosophy is a failure, for note what advantages I have. I have a new and correct understanding of heat, electricity, the nervous force, a new atmosphere, a definite understanding of cohesion, and a repulsion never before stated, a new atomic elemental matter, force is materialized, and I can place my finger on every act and actor, and with each of these there are scores of new things. Therefore I can have no excuse if I fail, for it required a high order of ability to work out the above explanation.

BREATHING AN ELECTRICAL PROCESS

The physical apparatus and the electrical action of breathing can be seen and understood as accurately as the telegraph apparatus and the flow of the electrical current in sending a message. And in addition to this the collection of an excess of electricity that is sent into storages, and the whole equipment and process more perfectly represented by an electrical plant that furnishes light, heat and power.

For the general reader it will be better to review than to refer to former illustrations. A chemical electrical battery consists of an acid solution that will dissolve a

metal chemically, or separate it into its atomic elements and zinc is here used. The solution is called the electrolyte, and the metal an electro-positive. Now another metal is placed in the electrolyte that will not be affected, and which is named the electro-negative metal and in this case copper is the metal. But let it be remembered that positive and negative are mere terms of relationship in electricity, indicating the direction a current is moving, exactly like the source and mouth of a river when known, inform as to the direction of the flow of the water. Source corresponds to positive, and means a higher elevation than the mouth, and higher or greater quantity of electricity than the negative, hence each flows from a high to a low always.

Now the chemical action sets free the cohesive Rx in the metal into the solution which increases the quantity of Rx in the solution or electrolyte, and would heat it if it were not for the copper which is negative with regard to the fluid. But instead of heating the Rx flows over the copper, from the above principle, and thus we have a current of electricity. Now the circuit of wire outside the solution is carried over and attached to the zinc which is negative with regard to the wire, while the zinc in the solution is positive to the fluid.

Let it be noted that the essential thing in the battery is, not only the securing of a supply, but a constant supply of Rx, and that it is the inherent repulsion of Rx and its varying affinity for different substances that produces the current. Let us now compare the battery with the apparatus of respiration.

The atmosphere is the vast ocean electrolyte in which the Earth is submerged, and in this human battery the air is the electrolyte and the body, the lung tissues and

the nerves constitute the apparatus. The vagus, or pneumogastric nerve is the wire circuit outside of the lungs, and the connections in the direction of the current are, the cilia of the air cells corresponding to the copper of the chemical battery, and these form the sensory nerves which lead to the medulla oblongata, which corresponds to the electric telegraph key; and the motor nerves starting from the medulla lead to the muscles and blood vessels of the lungs, heart, stomach, liver, spleen, and the sympathetic ganglia, all of which constitute the zinc of the cell, and these consume the current and thus keep a constant low potential. They are the mouth of the river. These motor nerves terminate in the muscles and around the blood vessels in fine branches with ends like a cilium. The current is consumed in heating the blood and producing muscular action. The high potential is always at the cilia and is constant, and may be considered as that of the air, which has a constant weight pressure of 15 pounds to the square inch, and which will presently be amplified. Therefore at each inspiration of fresh air the cilia which collect a charge of Rx that fills the sensory nerves to their highest potential to their termination in the medulla, for they were exhausted in expelling the preceding breath. This raises the tension in the medulla which at once sends a charge over the motor nerves, lowering its own tension and that in the sensory nerves, and the tension is lowered in the motor nerves, by the current heating the blood and producing muscular action, as above explained, and the apparatus of flesh is ready for a new charge.

Between the two batteries there is only the difference of tension in a scientific distinction. In the chemical battery we create a high potential and use the force

while it flows to an equilibrium: In respiration a low is constantly created which induces a flow from the level tension of the atmosphere. One reason, and there may be other causes, for the depressing effect of damp weather, is the lower tension in the air, and in dry, sunshine weather the higher tension tends to physical buoyancy.

In the explanation I have given oxygen was not mentioned and was not needed for a complete answer, for we know that the bombarding Rx of the air is continually passing through matter. When one looks through glass at the blue sky the light Rx is reflected from air molecules. The same impingement of Rx takes place from the air in the lungs to the cilia but they are so constituted and arranged that they divert Rx into an electrical current. Now the oxygen and nitrogen molecules of the air undoubtedly hold Rx with a weaker affinity than the cilia, and there is a probability that some Rx in the electrical current may be obtained from the molecules, and especially from the oxygen, which may be combined with the carbon thrown out from the blood in the lungs, producing the CO_2 found in the exhaled breath. This must be the case, or else the carbonic acid is exhaled direct from the veins of the lungs. That the former must be true is made quite certain by the effects produced by breathing other gases, and especially undiluted oxygen.

It must be understood that Rx is a new material element that the physicists, and especially the physiologists, have not dealt with, nor supposed in existence, in their experiments and explanations. And I have deduced my explanation from the data they have secured. The reason I have met with no obstacles is that they supposed a force to exist in or act upon

the elements they could catch and measure, while I have caught the force and found it to be a tangible element.

This is a reasonable, logical, scientific, tangible, provable explanation of the apparatus and force of the function of human Respiration. It is without a supposition, without a missing link, without a possible contingency against the perfection of the mechanism and the adequacy of the vital force, and can be confirmed by every cause that in any way whatever affects the force, action and purposes of this vital function of Life. And the positive and only possible conclusion is that,

ELECTRICITY IS THE NERVOUS FORCE OF ANIMAL LIFE

How clearly does this disclose the cause of every observed phenomena of respiration? I shall have to note a few to prove true some of the hard restrictions thrown out against the "oxygen theory."

First we breathe faster when we exercise because more Rx is required by the terminals of the motor nerves in producing muscular action, and this lowers the tension there just in proportion to the rapidity and violence of the muscular action. This lowers the potential in the medulla which is equivalent to raising the potential in the lungs. The air is the only source of supply and to meet an extra demand more air must be taken into the lungs, and more Rx is absorbed proportionately from the same quantity of air, or the quantity consumed is regulated by the tension or potential in the medulla. Our breathing is very regular while the quantity of Rx varies considerably without effecting muscular action. The tension in the medulla is self-regulating, and the degree of tension is set according to our muscular activity. That this true, all can

bear witness for the occasional deep breaths. They are merely for correcting this established tension.

Then, second, there is that greater problem of heat, maintaining an even temperature with such varying fluctuations of the temperature of the air, and especially the severest test for "oxygen" of a variation of 125°. It has already been partly solved above. The cause of lowering the tension in the medulla was shown above to be from the loss of Rx in muscular action, but in maintaining the heat of the body the great loss is to the blood which is the hot water in the pipes that warm the flesh. Now the cold air cools first the lungs themselves, and the lungs are the first to receive heat from the blood. The cold air therefore greatly lowers the tension in the medulla and it extracts more Rx from the air which is at once used in heating the lungs, and but very slightly increases muscular action. Hence ordinary changes in the temperature of the air have only a negligible effect upon the number of breaths. But in breathing very cold air the lungs cannot maintain the regular degree of heat, 98.5, and look after the demands of the whole body as usual, hence the drain from the extremities must be checked or they will freeze, and freezing to death is due to the stoppage of circulation in the extremities first, and finally the returning of blood to the lungs from the body so cold that the supply of Rx cannot maintain a life temperature, and the circuit breaks.

Now in this connection we can see why exercise will prevent, or longer prevent freezing to death. The Rx that is used in the movements of the muscles is diverted into heat, and the movements increase respiration action and hence more Rx is collected from the air.

The older physiologists located the generation of the

heat of the body in the lungs, but the latest have located eighty per cent of it as resulting from muscular action, and we can see that the latter are correct as to the location, but there is a question as to the per cent, and they will need to correct their understanding as to what heat really is. The per cent of Rx liberated by muscular action may be quite closely determined by experiment, but I venture that it is not nearly equal to this per cent. It can be readily seen that, logically, nearly all of Rx that enters the body and becomes nervous force has a heat effect before it again escapes, or is concerned in maintaining the general temperature.

The motor and sensory portions of every nerve constitute a circuit, and like a metal electrical circuit they are always charged. In sending a telegram the same Rx does not pass from the sending to the receiving instrument. The quantity thrown into the circuit and lost by the contact and break of the key respectively is supplied by the battery. Every action of the nerves is similar, and when we touch anything we set the current in the circuit in motion. The impression flashes to the brain over the sensory branch and a like quantity flashes back over the motor. This produces the heat and aura of the body. We constantly feel the touch of our clothing, or the air, and which is usually of warmth or chill. The clothing is kept warm yet is constantly losing heat. It is this action that also furnishes the force that keeps the blood moving in the capillaries and the care of the tissues (anabolism or katabolism). This care is solely concerned in the cohesion of the elements, Rx is the cohesion of all matter, Rx is this current and supply, and hence we do not have to rush away to the shrine of the clairvoyant Hypothesis, who only pretends to know, to find out the effect of causes that we see and know.

Apnœa, as partial or permanent cessation of respiration is scientifically known, may have several or one of several causes, some of which have been mentioned in discussing hysteria, and the "Vital Knot." Anything that will break the tension in the medulla oblongata, or especially destroy the sensory current from the lungs to the medulla will affect the rate of breathing, and may be fatal. There are many gases that directly affect the cilia and at once show their effect upon respiration. Carbonic acid gas is injurious in a greater per cent than that found in the atmosphere. Any accumulation on the cilia that checks the flow of Rx will soon prove fatal. One of the most deadly gases is *arseniuretted hydrogen*. It is said that one inhalation of this gas by its discoverer, Gehlen, cost him his life. It undoubtedly broke this sensory current, which would stop all the other impulses from the medulla. Or it might have reversed the current over this nerve, which would have the same effect. Now there is no possible explanation with O and CO_2 in the blood as the cause of respiration. The present explanation attributes the cause mainly to a deficiency or an excess of carbonic acid in the blood, but this could in no wise account for the sudden death of Gehlen, nor the immediate suffocation from breathing carbonic acid gas. I would not contend that the quantity of carbonic acid in the blood has no effect upon respiration, for perfect respiration depends upon pure air and perfect blood. I have suggested that there may be a magnetic section in the nerves that preserves the direction of the current, and it may be that poisons, which destroy the life property of the blood may have their baleful effects on this section. However, there is only the possibility of a safeguard that suggested to me this probable magnetic condition.

Death from apnœa often follows a sudden loss of blood from an artery which has the effect to so lower the tension in the medulla that the great life essential, pneumogastric, electrical circuit is broken, and that destroys the power of the grand engine, the heart, and the magnificently sublime mechanism of matter has lost its dominion, and must return to the caprice of common elemental actions.

TEMPERATURE AND SUMMARY

I have already slightly touched upon temperature, but since I started out to demonstrate that Electricity was the Nervous Force by proving that only by this understanding could the temperature of the body be accounted for, it will be appropriate to use the same in the summary as the main support around which the other evidences will gather. The explanation we have been so long striving to reach may be briefly stated thus:

THE TEMPERATURE OF THE HUMAN BODY AND OF MOST ANIMAL LIFE IS CREATED AND MAINTAINED BY ELECTRICAL CURRENTS WHICH ARE NOW KNOWN AS THE NERVOUS FORCE.

Vegetation does not use the electrical current, and the very lowest forms of animal life may not, and for that reason I have not included all animal life in the definition. Vegetable life depends upon capillary attraction and the universal tension of Rx produced by the atmosphere. It requires a system of nerves to employ electricity. A large portion of vegetable life survives freezing but animal life does not. It is possible to revive animal healthy life before distintegration has taken place anywhere in the system, by bringing the whole body to the proper temperature, employing

forced respiration and using the proper current of electricity. But it is more probable from suffocation and drowning, if in the latter case the water can be taken from the lungs, and doubtless many have had the pneumogastric current started without the use of the electric current, by proper manipulations of the body. The currents in the body of the manipulator would conduce to this end. The principle is explained under "Induction" in the chapter on Electricity.

I. Rx has been shown to be heat. This is the one controlling fact that makes the new explanation possible, and since it dislodges the oxygen theory of combustion, the point is virtually settled. Oxygen is so generally present in the generation of heat that there is no surprise that it has been thus considered, but since heat is generated without the presence of oxygen, as in the incandescent lamp and all electrical heaters, the point is settled that oxygen is not the essential thing, and that Rx is, for it is always present wherever heat appears.

II. Rx has been proven to be light and electricity, and since they are the only forces that produce heat without the presence of oxygen, and since they generate heat in the body, the oxygen theory of the heat of the body can not be maintained.

III. Currents are essential to electricity and it has been shown that the body has a perfect system of electrical conductors and storage, and that the nervous force employs this system precisely as though it were electricity, and since there is no other force known that employs such a system, and especially since all disclaim to know what the nervous force is, there can be no ground for doubting that they are one and the same, and axiomatically, since no two things can be identical in

parts, performance and purposes and be different things, therefore Electricity and the Nervous Force are one and the same thing.

It is true that some claim that it is a form of energy and designate it as "Nervous Energy," but present "energy" is only hypothetical, and hence it is true that no founded claim can be made by present science as to what the nervous force is, while the New defines it as the cohesive and repellent attributes of Rex and atoms. With these every physical fact of nervous activity can be accounted for.

IV. The Earth receives its heat directly from the Rx radiated upon it from outer space and over 99 per cent from the Sun, while man secures it from chemical action (combustion) and the electrical current, which, when steam power is used to generate the current, is merely using the repulsion force of Rx to transport Rx for its heat effect or function at some distant point. When water power is used, the gravitational force of Rx is used for the same purpose.

Now I have shown that the body has these two ways of producing its heat. Combustion requires air, not because of the oxygen itself, as now supposed, but because of the Rx it contains. And it is now claimed that the food in the stomach and the blood in the lungs are warmed by combustion, but they have not pointed out how they get the air which is required in their comparison of coal in the stove, while I pointed out in the explanation of respiration, that the Rx collected by the air went directly over the sensory nerves to the medulla and from there to the stomach and lungs over the motor nerves, and therefore I have shown the cause for the combustion which was not given. Let no one lose sight of this last disposal of the "motion theory" of heat. For

this combustion is accomplished without air, *but by the presence of Rx.* Therefore Rx in the air is the thing or the Rx on the oxygen.

Therefore, also, this proves my statement in the first of the discussion that heat was not generated in the stomach by the food, but the food is absolutely essential, for it holds the Rx sent there over the motor nerves. There has to be a storage and carrier, and this is what the food is for, and the maintenance of the carrier. But this combustion may be considered one of the sources.

The other source is from the electrical, or nervous currents, for after every motion of the body the Rx that caused muscular action enters into its heat function. And present physiology says, that 80 per cent of the heat is liberated by this last method, of muscular action, while I believe with a new investigation, and with the correct understanding of what heat is that the per cent will be greatly reduced, but the per cent increases with the amount of physical exercise. It is minimum while we are asleep and increases to the most violent exercise.

This is not only a conclusive argument for my contention, but it relieves a hard problem. For now it is considered that all muscular movements are at the expense of muscular tissue which is not borne out by the facts but which is a necessary conclusion from the old theory or from the present understanding of energy and the transformation, or transference of energy. Hence we can now see that the electrical current can act upon the tissue without destroying it. For with the old understanding, if there is destruction anywhere it must be throughout the muscle concerned, and however small we make the amount in any single place, the

aggregate would be a damaging factor in the muscles. From this foundation the physiologists have figured out that we have worn out a body in seven years and hence have a new one. Prof. Steele says in his Chemistry, that the muscles of the body are burned out about every eighty days, and that we have a new heart every thirty days. He said this in my school days, and I have met with no other estimate since. It supports my contention, and a different estimate of time would be immaterial to the principles involved.

V. The fact of increased perspiration with increase of muscular action indicate that a material force actuates them, and Rx and the conditions accurately meet the facts of that force. The electrical tension is always low in the muscles, consequently the flow of Rx is into them, which produces a flow from them which results in heat, and the flow of heat is always in the direction of cold, and the surface of the body is the coldest portion. Therefore Rx should be driven to the surface, and from the surface by the greater internal pressure. Now Nature has made a wondrous provision for just this contingency, the "conditions" referred to above. There is a vast number of little perspiratory glands in the true skin, and usually called sweat-glands that have minute tubes reaching to the surface. Now the Rx sent out as muscular force cannot collect and it could not get away alone. Hence into these glands it carries water and forces it to the outlet of these tubes where it evaporates. If there are any atoms the glands cannot use in the purposes of the flesh or skin it is carried with the water in the tubes and also evaporates. The quantity of this waste varies from a fraction of one per cent to three per cent of the water, according to the health of the body.

And we can get still a little closer and see just why it cannot be used and why it floats away with the perspiration. The principle of affinity of Rx and atoms gives a logical and complete answer. An atom or a molecule suited to the need of the body will have a stronger affinity in that place than its affinity for water, or the blood, if not it is carried away by the glands.

Then the affinity of water for heat, or heat for water, is of such common understanding that everyone sprinkles the floor to cool the air, hence no one can fail to see how simple, beautiful, and marvelous are the provisions here for maintaining a constant electrical current, and that Rx is the force in all of the functions.

How it is emphasized when we consider that there should be a rapid accumulation of heat from violent exercise, and then witness that such is the case by the accumulation of drops of sweat, because the flow was so rapid that it could not escape in invisible evaporation, which here is known as perspiration.

VI. The new explanation is the only one that can explain a higher temperature in the hand or foot than in the lungs. Neither the blood, nor muscular activity can answer, for the blood should be colder, and there is at these times virtually no motion there. Since there may be some young readers who do not now conceive the cause, I will give it. The principle in electricity is known as short-circuiting of a current. If an electric light wire touches a nail or small portion of metal the current will flow into it and set the building on fire. This is short-circuiting. When the foot is diseased or injured in certain ways a short-circuiting of the terminals of the motor nerves results, from the clogging of the blood, or bruising of the tissues, and Rx collects

faster than the glands can remove it, and it is said to be feverish.

VII. I earlier made the claim that doubtless there was no more heat liberated in digestion than in the preparation of the sap of vegetation. But during digestion the temperature of the stomach is raised and hence it was concluded that it was due to the process of digestion. Now, however, we can see from whence comes the heat that causes the extra temperature. The motor nerves of the medulla go direct to the stomach, and when that organ is distended with food the muscles are stimulated to action, which consumes the current of the motor nerves. We have just seen that muscular activity generates an excess of heat, which at the surface of the body is carried away by perspiration, but the excess in the muscles of the stomach must enter the food, and therefore the temperature is raised from this source and not from the food. But further, to effect chemical action, that manufactures the blood, requires more heat than the food can supply, and I must not neglect the proof of this declaration. Katabolism releases heat (Rx) by tearing down molecules, hence, the tearing down of the food releases heat. But anabolism requires heat in building molecules, therefore, the relative sizes of those torn down and those built up determine an excess or lack of heat from the complete process. The blood corpuscles are larger than those of the food, hence, heat must be supplied to effect digestion. Further, this is proven by the digestion of every meal. The beauty of the situation is that with the new explanation we see just where the heat comes from (direct from the air), of what it consists (Rx), and just how it is delivered to the digestive apparatus (by the motor nerves from the medulla oblongata).

Vegetable tissue is built up mainly of atomic matter while animal tissue requires molecular substances. This is why they both require heat, and why the animal the greater quantity for its molecules, or especially the molecules of the blood are so much larger and more complex than the vegetable. I know that it is claimed that a thermometer will indicate a higher heat in a bed of geraniums at times, but whenever heat appears in chemical action, it will be found that katabolism is taking place faster than anabolism.

All of the above is completely borne out by the facts of hibernation and estivation, which need not be pointed out to those who are posted on these conditions of animal life, but since so many are not posted, the subjects should be briefly reviewed.

Hibernation is a state of inaction and torpor in which a large number of animals pass the winter. There are a limited number of animals that pass the summer or heated season in a similar condition, which is known as estivation. The phenomena is quite general among cold blooded animals, both vertebrates and invertebrates, and especially where the animal mechanism for adjusting the bodily temperature is deficient, and in places where the weather conditions for a considerable portion of the year become inimical to the usual life of the animal. Bats, hedgehogs, rabbits, bears, reptiles, snails, frogs and insects represent the orders of animals that are subject to these periodic conditions. In most cases the active period is a stage of preparation, the animal taking on an extra quantity of fat, which serves as food or fuel for the dormant state.

When in the state of hibernation there must be a radical change in animal functions, and it is found that alimentation and excretion cease, the temperature is

lowered, circulation is greatly retarded, and respiration becomes minimum, and all but ceases in some cases. It is claimed that a hedgehog has been held under water over twenty minutes without injury, while in its active state it would drown in three minutes.

The great problem of the two philosophies is to reasonably account for this peculiar condition. We can at once see that the old theory of combustion by means of oxygen from respiration cannot hold, for the animal must have enough heat to prevent freezing. Then I have pointed out that constant katabolism is not essential to securing animal heat, and since it is now claimed that 80 per cent of heat is released by muscular action, this source of supply will not explain, for muscular action is minimum. Now, on the other hand, it is most obvious that the new explanation of heat, and the new explanation of nervous force meet the case perfectly.

Rx is heat, and Rx is the nervous force of animal life. Rx is the cohesion of the animal tissues, and hence all that is necessary is only a uniform quantity to maintain the temperature and keep the tissues right.

When the animal is in this state the requirements are minimum for Rx, and the fact that respiration is so low shows that the supply is minimum, and at the same time is a most forceful argument for my contention that respiration is the real sources of the supply, and not oxidation. The largest demand for Rx is in the muscular action of the heart and when released is heat, and since it is wholly within the body it is all conserved.

It is claimed that in the condition of hibernation that the pulsations are kept up by the left side of the heart which is more irritable than the right. It was shown that the motor nerves from the medulla oblongata carries the motor current to the heart, and it logically

follows that with a minimum temperature throughout the body that there must be a minimum tension in the medulla circuit which can readily be maintained by the sensory nerves from the lungs with very feeble respiration, or the variation of the blood in the lungs might be alone sufficient to keep up the action explained in the medulla, which required merely a variation in tension, which the blood alone might effect. Thus the principle explained for controlling this tension through the lungs, heart and digestive organs holds here, for the warm blood from the lungs enters and leaves through the left side of the heart, while the cold venous blood passes through the right side producing a potential variation both in the heart and the lungs, which is the sole requirement for alternate activity.

The Tenrec of Madagascar estivates in the summer, and it belongs to the same order of mammalia as the hedgehog which it resembles, and has similar habits. There are species of reptiles, batrachians, lizards and tortoises that bury themselves in the mud in places where drought is periodic. But they have not been investigated as fully as those that hibernate.

In these cases I have considered only the one cause of temperature, while there may be other and physiological causes of the existence of these animals. Insects have been known to commence hibernation on warmer days than those that had just preceded. Because of the regularity of the woodchuck of the Adirondacks sleeping from the autumnal to the vernal equinox, Marshall Hall favors the probability of a physiological cause, and that cold is a predisposing cause.

Hence the facts of hibernation not only supports the contention that electricity is the nervous force, but is

one of the most conclusive proofs that Rx is heat, and the cohesion of matter.

VIII. It has been recently claimed that the aura of the body can be seen under the right conditions. The electrical character of the nervous force indicates that such should be possible. Phosphorus is luminous in the dark because its affinity for Rx repels the bombarding Rx of the air with an enough greater velocity than oxygen and nitrogen, the elements composing the air, to produce a velocity sufficient to affect the optic nerve, although not the velocity of incandescence. Therefore, owing to the electrical tension of the body it should increase the velocity of impinging Rx sufficiently to be detected.

IX, X, XI, XII, XIII, relate to the five senses, which have already been sufficiently treated.

XIV. The storage of electricity is very conclusive. I can hardly be expected to make a comparison with the present conception of the nervous force, for it is an hypothetical force, and that it could be stored would be merely hypothetical. But in the case of Rx we have a material thing and know the material means by which it can be stored for electrical use, and it has been shown that the conditions in the system admit of just such a storage.

XV. Yet the crucial point brought up against "oxygen" has not been mentioned, nor fully explained: Or rather the crucial points in the explanation have not been set forth. But the fact that electricity is the nervous force has already an overabundance of proof. In other words, the real causes of the uniform temperature of 98.5° are now to be given.

The primal cause is the blood and the primal means is the electrical tension of the medulla, or of the gray

matter of the medulla which is concerned in the regulation of the sensory and motor fibers of the pneumogastric nerve. Accessory causes are the blood and the smallness of the nerve fiber. The medulla is the "safety valve" of the temperature of the body. The perspiration, and especially the visible, or drops of sweat, correspond to the engine when it is blowing off steam. This tension is adjusted between pure blood in the lungs and the gray matter of the medulla. The lungs and the heart are continually lowering this tension, while the cilia and sensory nerves are as continually restoring it.

The key or pitch of this tension is a blood temperature of 98.5° Fahr. with perfect blood. And when we speak of perfect blood it means that the whole general system is in perfect balance or health. The blood becomes impure, which really does not necessarily mean disease, by the presence of elements that the body cannot use in perfect construction and maintenance. This usually precedes sickness, or leads to disease by storing the different parts with improper material. This impurity affects the nerves and the medulla in such a way that the tension is raised which causes a rise in the temperature of the blood, and which is the first indication of disease. This increase is termed fever and the kind of fever will sooner or later develop with other symptoms, and depends upon the kind of poison that has permeated the system. This change of tension is not only told by increased temperature, but also by a more rapid pulse. The heart beats faster, the whole system is unbalanced, and this more rapid flow of blood has a tendency to make all matters worse, at least, for a time.

Now the primal cause of the uniform temperature

throughout human life is the God-given nature of the blood, and this perfection is maintained by the electrical tension as given above. For the blood remains at an even temperature throughout life with the slight increase of the fraction of a degree in infancy and childhood, when the apparatus is all new and the growth rapid, and as small a decrease in old age.

This does not in the least make it more possible for the "oxygen theory," which is virtually the "motion" theory of heat, to maintain this marvelous level, but demands something as accurate, simple and single as atom Rx in the electrical current, and with as delicate an apparatus as we find in the medulla oblongata and its accessory parts. For it is Rx that regulates the electrical currents of Rx, and it is Rx in the molecules and corpuscles that determine their purity or perfection.

This is the temperature at which the corpuscles or molecules of the human blood are perfected. I have pointed out that there are more atoms in every molecule than chemistry now contemplates; that water is not just H_2O, but H_2OR, for in every molecule of water there are just as definite a number of Rx atoms as there are of hydrogen and oxygen and the same is true of all molecules. Then there are definite conditions for the formation of every molecule. The red and white corpuscles and all the molecules of the blood are perhaps the most highly organized of any in all nature, as was indicated in the discussion of No. VII, and the same accuracy must be observed in a perfect corpuscle. Now each substance has its specific heat, which also means that each molecule must have its specific heat, and all these things are just as accurate as is the size and nature of the atom. Hence these

determine the accuracy of the structure of the nerves and the gray matter, for they are nourished by the blood and are strong or weak according to the purity of the blood.

Therefore pure blood has a specific heat capacity, and its normal health degree is 98.5, and this determines the electrical tension of the medulla, which in turn corrects the variations in temperature, and preserves the health of the body. Of course, this means that all the other adjusting and correcting methods of the body are used, and that this is only one of them, but *the* one essential to all others.

I think that there are no facts that will militate against the explanation as above given, namely, that the initial cause is in the blood. But some doubtless will be inclined to believe that the primal cause is the tension of the medulla oblongata, for such was my first deduction. But the fact is, that whether in the medulla or the nerves, the tension is made what it is by the blood, and it follows that a change in the blood must effect a change in the medulla, and hence this brings about the conditions that correct or wreck the condition of the blood, renews health or destroys the mechanism.

XVI. I will now add confirmation facts from the most recent experiments with muscular and nervous tissues, as set forth by the latest physiological texts. They are of greater weight than had I made the tests, for I might have been biased in my observations and conclusions: I will admit naturally but not intentionally. By the use of stimuli the experimenters have arrived at the following conclusions:

(I) Nervous tissue is irritable. (II) Muscular tissue is irritable. (III) Nervous tissue has the capacity of conduction, carrying something throughout its extent

that displays force. (IV) Muscular tissue has the power of conductivity. And the following effects have been observed as the result of stimulating contractile and irritable tissues:

(I) At the point of a nerve where the stimulus is applied some change is noted, which is the manifestation of the invisible irritability of the nervous tissue. (II) This internal change is propagated along the nerve trunk to the muscle the nerve serves. (III) It is delivered to the fibers of the muscle through the end plates of the nerves which lie just within the sarcolemma of each fiber. (IV) It is so conducted through the contractile substance of the muscle that contraction practically takes place at once through the whole muscle, which visibly changes its form. (V) Internal changes in the muscle and nerve take place at the time of the change of form. (VI) These internal changes have been found to be chemical, thermal and electric.

In experimenting on the contraction of muscle by applying stimuli to the nerves they are now using mainly the electric current, and the same action of the muscle is obtained as it exhibits in life. I cannot take up the explanation of the experiments, but will give the laws of action that have been demonstrated. Instead of using the common terms of positive and negative poles to indicate the direction of the current, they use anode and cathode, respectively. It will be understood that a nerve is in the circuit of an electric current which has a key for making and breaking the current. The following are known as Pflueger's Laws of Electrical Contraction:

Law I. The make stimulus is cathodic; the break stimulus is anodic.

Law II. The make or cathodic stimulus of a current

is more irritating to a nerve or muscle than the break or anodic stimulus.

Law III. A strong constant current decreases the conductivity of a nerve in the region of the anode during the passage of the current and in the region of the cathode after removal of the current.

Law IV. The passage of a constant current through a nerve modifies its irritability, increasing it in the region of the cathode and decreasing it in the region of the anode.

If I have established the fact that Rx in currents is electricity, these laws, beyond question, confirm again that currents of Rx are the nervous forec of the body, which is therefore *electricity*.

The reader does not need to be told that all these results can be readily accounted for with Rx as the nervous force, and that they are necessary consequences with the electrical application of Rx. The tissue of the muscles, like that of the nerves is fibrous of a reddish color, and small bundles are enclosed in a sheath of connective tissue, known as the perimysium, and the whole muscle in a sheath of glistening connective tissue, the epimysium, and all of which indicates electrical construction.

The most important result of the experiments is the fact that chemical and thermal stimuli will not act upon the nerves to produce the effects observed, and that the perfect effects can be secured only by the use of the electric current. The requirements of a nerve stimulus must be sudden in beginning and ending, and instantaneous in its duration, and there is only one thing known that will meet these conditions, electrical *Rx,* and that is why electrical apparatus has been specially designed to make the experiments to which I

have alluded. There are other stimuli that have been used but they do not give a perfect test. Extremes of temperature, as a touch with a highly heated glass rod, a blow with some small pieces of metal, and these are electrical in character, especially the glass rod, for the Rx as heat gives the suddenness required, but its condition, quantity and application are not identical with the electrical current which is identical with the nervous stimulus of the living organism. But I will not say that the experimental action is identical, for in the very nature of things it could not be, because the living mechanism is perfect, complete in every detail, including the generation and regulation of the current, and the environment is special and right. But in applying the electrical current this perfection can be only approximated. The muscle is not in its normal condition or environment, the application is different and the current could hardly be brought to the proper pressure. Therefore, since the most perfect attainable electrical experiment cannot be made to agree with the natural, and since the results obtained, however, so accurately imitate the natural, can there be any doubt that Rx is the nervous force, and that all present known discrepancies are due to the impossibility of making a perfect test?

With the electric current they have tested the muscles from a single healthful movement to tetanus: have noted the change in form, and all the modifications occasioned by temperature, drugs and load: have determined the amount of work of a contracting muscle under the various conditions of stimuli, time, and severity: have approximated the chemical changes and determined the thermal and electrical changes resulting from the action of the current upon the muscle,

and have deduced the following law. *The work which a muscle can accomplish varies as its volume, or its sectional area multiplied by its length.*

CONCLUSION

As we turn over the defined Nervous Force of the body to the metaphysician I have prepared myself for his probable objection, that it is altogether too tangible for his purpose, that it is too material for his immaterial products; that his mentality requires something as mysterious as the elusive "Ether"; something, that, while it effects, produces sensation, must be too ethereal to be perceived by sensation, and thus leave me with an unused quantity of capacities of electricity on my hands.

As a first impression that may seem merely a felicitous digression, or, at best, an innocuous conclusion. But I shall have to turn it to a forceful purpose, if not argument. For as I view the all too brief, plain alignment of the tangible facts relating to the Nervous Force and the Electricity of the new Philosophy, I do not see where there can be found any closer or more forceful argument against my conclusion that Electricity is the Nervous Force of the body, than is contained in these imaginative objections.

It is without a single hypothesis, without a missing link, in perfect accord with all experience of physics and physiology, and in every particular is experimentally provable. And only second to all of this, it as completely accounts for the great mystery of the uniform temperature of human blood. The materiality of the force is established, which still further supports the Third Fundamental Proposition of this philosophy. The wonderful strength of muscular tissue is scienti-

fically accounted for: Since Rx is the cohesion of all matter, and since the muscles are stimulated by the nervous current, muscular action is the cohesive act of Rx. Here is an argument that can be carried back to still further support my declaration that cohesion is at first a motion act becoming stationary. The establishment of the identical relationship between vision and hearing, and between these and the electric current, besides supporting each of the four new understandings of these phenomena, is one of the most remarkable and invulnerable chains of evidence to be found in any physical philosophy, and is exceeded only by the longer and unbroken chain of Rx which binds together every chapter in this work, and upon which like sparkling gems hangs all the phenomena of Nature.

Rx as light paints pictures on the photographer's film, and who knows but that the metaphysician may persuade us to believe that, in a similar manner as the agent of hearing and vision, Rx makes a corresponding imprint upon the convolutions of the auditory and optic nerves? The potency of his reasoning may be sufficient to compel us to admit the possibility, if not the plausibility of his conclusions. He may point out that as Rx, a material factor, added to the silver of the film makes a new compound, which is the picture, so this material factor added to the more sensitive and perfect composition of mentality produces a negative, usually of a transient character but which may be transfixed and hung in the special cerebrum gallery to which in harmony its character pertains, and labeled by a visual sign for future contemplation. He may insist that the quantity and arrangement of these negatives determines the wealth and strength of mentality, and that the enlargement of the galleries is the evidence:

That the optic negative may be that of a horse, and the auditory that of the word horse, and the two will ever be associated, and that, except in rare cases, every subsequent visit to that gallery will reveal the original negative still more distinct than the myriad later imprints, and moreover that the original setting, the environment, will appear. He may even call upon me to state that I never spell the word, opportunity, but that I see the distant home, long since vanished by the march of progress, the whole setting of an upper room, a devoted patient mother, and a poor youthful speller guessing at the many ways he could successfully spell that word. And thus he may show how there are trains of thought as well as trains of cars.

He may prove that every sound has its material association: that a strain of music may conduct the aged listener into the closed and forgotten gallery of youth and reveal the untarnished pictures of childhood.

These possibilities are therefore merely additional, and unneeded evidence of the proof of the fact that Electricity and the Nervous Force are one and the same thing. I have diligently tried to find evidence for supposed opponents to ward off this conclusion, and have been unable to find any of the least scientific value. The real pleasure of our work comes from the conviction of its genuineness, and the great satisfaction of this closing chapter is its harmony with and confirmation of every other chapter of the work.

CONFIRMATION

As conclusive confirmation not only of this last chapter but also the chapter on Electricity, I am pleased to add the article below by permission of the editor of the *Chicago American,* which appeared in that paper

September 27, 1913, and I am disposed to use it because it is appropriate for the closing, as my manuscript is in the hands of the printer.

It is by an eminent astronomer and scientist, Professor Garrett P. Serviss. It is a resumé of the most recent progress of science in this field. Although I might have collected the same facts they would not have the same force as they will coming from a scientist with a wide reputation. Now there is a very interesting problem here that I will set forth before quoting the article.

Professor Serviss does not know of the new discoveries and interpretations contained in this work, and therefore the problem is, what will be his attitude towards them, since they conflict with the philosophy that he has so widely exploited in his books and scientific articles? Will he be able to secure counter argument for that herein contained, and made possible only by the material discoveries? But it becomes more interesting to the reader, as well as to myself, when he recalls that I have stated that in 1889, when I made my first discovery, none were inclined to investigate its value, and that from all the exploiting that I have given it since that time, no one has taken issue with a single fundamental proposition, while able minds that have fully investigated have accepted the New Philosophy.

But since the problem attaches to all scientists generally I will allow the reader to finish the many possible solutions, and turn my attention directly to the argument in the article, for the New.

MYSTERIES OF SCIENCE AND NATURE

"Electricity seems to be the great connecting link between the various phenomena of nature. If we could once thoroughly under-

stand electricity we might understand all the natural forces, and life itself.

"If you put any two unlike substances in contact a difference of electric potential instantly arises between them; one becomes positively and the other negatively electrified.

"If you stretch a rubber band minute electric forces appear in it. The same thing happens if you change the form of a drop of mercury or of water.

"Every motion of your body is accompanied by electric variations. A whirling wheel, a growing plant, a forming cloud, a fly buzzing through the air, a bullet speeding on its way, a wind blowing over the earth, a nebula condensing in space and a thought arising in your brain—all these give rise to electric manifestations, proportioned to the physical forces called into play.

"Whenever you bend your arm, or open or close your fingers, or strike a blow, or wield a pen, or play a piano, differences of electric potential, capable of measurement with modern instruments, show themselves at various points in the muscles that produce the motion.

Through Electricity the Condition of the Heart May Be Ascertained

"Every beat of your heart has its electric accompaniment, and Dr. P. Goggia has shown that by means of electric instruments recording the differences of potential produced by the action of the cardiac, or heart muscles, the state of the great pumping engine of the human body as to health or disease may be ascertained.

"Messrs. Phillipson and Menzerath have carried this method further. They have applied it to the study of the electric effects of our thoughts and emotions.

"If a sudden light is flashed into the eyes a change of electric potential occurs in the body. The same thing happens when a sound strikes the ear. These things produce emotions having an external physical origin. But like changes occur as the result of an internal emotion, arising from the silent passage of thought through the brain. If the subject who is being experimented with is asked to make a simple arithmetical calculation, such as multiplying two numbers together, a measurable difference of electric potential is immediately noticed between his two hands. If his mental excitement is increased the difference of potential becomes more decided.

"Always it is the right hand which becomes positively electrified with regard to the left. This is true even if the subject is habitually

'left handed.' The mental activity seems to engender a slight contraction of the right hand, the surface of the skin on the back of the hand is distended and an electrically positive charge manifests itself there.

"At present these facts are mysterious; their explanation is not evident. But that explanation may be found, and, when it is found, a surprising light on the nature of the action of the brain, and of brain upon brain, will probably be the result.

"The connection between mental action and the electrification of the right hand leads to many curious reflections. The right hand is the scepter of the brain. When a command is given the hand is instinctively extended. That act, in critical circumstances—on a battlefield, for instance—is sometimes almost magical in its influence. It is as if the electric force, radiated from the extended hand, conveyed to thousands of brains the will and the mental energy of the commander. The soldier feels the electric impulse, all the cells of his brain set themselves in accord with the current of invisible force transmitted to them, he faces the way the pointing hand indicates, and, forgetting fear, forgetting self, experiencing only the overmastering influence of the directing hand, he plunges onward to death or to victory.

Powerful Influence Is Gauged by Amount of Mental Force

"The greater the mental force, the more powerful the influence. When the brain of a Napoleon was behind the pointing hand tens of thousands of men were transformed into an irresistible on-rolling wave that nothing could withstand.

"We do not need to seek long in the events of everyday life in order to find examples of the marvelous transference of one man's mental energy to hundreds and thousands of others, who go where he points, do what he wills, and, for the time being, become as it were, mere extensions of himself. We have long been accustomed to speak of men who readily command other men as possessing superior magnetic force, and we have always known that such men excel the majority in mental power. Now we, perhaps, are getting a clew to the nature of their influence, and, like so many other things, it reduces itself to electricity."

In this work quite every one of Professor Serviss' longings has been supplied. Electricity has been proven and applied to all the phenomena at present supposed to be accomplished by its magic, and in addi-

tion has been proven to be of far greater importance than supposed, namely, THE NERVOUS FORCE, while Hutchinson, the physiologist, asserts that it has been determined that electricity is not the nervous force. But we must remember that it was the old concept of electricity, which of course could not be made to fit into the requirements of the nervous force. This strengthens both the truth of Electricity and the Nervous Force.

In the chapter on Electricity I explained the principle and gave illustrations which he has increased in number in the first four paragraphs, which again settles the fact that the thing electricity has really been discovered. And the remainder of the quotation as completely proves that this same force and principle is the nervous force of animal life. In the chapter it was shown how the currents were secured and maintained, and some similar illustrations given, but here are more recent and more delicate electrical tests given, proving that the mind executes volition by means of the electric current.

In the last two paragraphs he expresses some facts but has not given the full explanation, for while ordinarily some minds can exert an influence over others, there are usually conditions that must be secured. In the case of Napoleon it was nearly as much the condition of the minds of the soldiers, their love of country and the glory of their chief, that had tuned their minds to be thus affected by any sign from him. It is quite similar to the "tuning" of wireless sending and receiving instruments. The same principle governs in all mental intercourse. All persons are easily interested by any subject with which they are familiar, not solely because of knowledge, but mechanically, because those subjects stimulate electrical action or currents. If I am not

trespassing too far into the domain of the metaphysician, I will say that doubtless every thought takes effect in an electrical circuit, and attention is best secured when this current is uninterrupted.

The connection between light and electricity is shown by a flash of light in the eye causing an electrical effect, or potential, as stated in the article, for I have shown that a current of electricity is really a condensation of light Rx, or that while light is disconnected Rx with light velocity, the weakest current of electricity is a solid file of Rx driven over a conductor by their repulsion. Hence this establishes an important point set forth before.

But Professor Serviss goes farther in the very first paragraph, where he says, "If we could once thoroughly understand electricity we might understand all the natural forces, and life itself." But the truth is that we now understand all the forces and only by them do and can we understand electricity.

But the important phrase that I wish to note is, "and life itself." I have all the time realized that some would contend that I had also discovered life, but I did not believe I had and did not desire to make a false claim, tempting as it is. I had mentioned this point to no one, when an M. D., who had taken deep interest in my work, verified my expectation, when he said, "Mr. Page, do you know that you can also explain Life?" I replied, that while the vital or dynamic force of protoplasm is pointed out, I was not prepared to say that life was discovered.

It was for the purpose of properly setting forth this aspect of atomic matter that I wrote "Creation or Evolution," but it proved too long, and the work containing 800 extra large pages, it was found advisable to omit

the same, enlarge upon the abbreviated treatment, and present it in a separate volume. But I will say, since the subject has in this manner come up, that the biologist has traced the vital spark of life to protoplasm and confesses that there is within the protoplasmic cell a dynamic force that cannot be located and Rx meets the requirements of that force, and it was for this reason that the Doctor made his remark. But to me there seems to be a principle above this, and especially in human life, to which this is only one of the means to the marvelous perfection, Life.

Although I have greater occasion than the novelist, the orator, or the poet to use the art of the rhetorician, custom demands the driest prose procurable, unadornable by simile, metaphor, or anything that, by the nicest measurement, would reveal the faintest trace of pleasure or impelling emotion. It is not a public demand. It must then be an inheritance from the early philosophers, to whom the splendors of newly discovered facts could not be told in painted speech, and believing that all eyes could see as wide and deep as theirs, placed their gems in geometric prose. Or they may have thought them quite too great to be intermingled with thoughts that require the colorings of fantastic draperies to have them pass current with the common mind. I am not pleased with the inheritance. For anyone unskilled in flowery eloquence, the toilers in the common fields of labor, viewing the simplicity and sublimity of the new order of things should find it native to his tongue. For, from illimitably beyond the narrow confines that furnished spells of mental energy, would come tripping in thoughts never dreamed of on a sphere so small as this; and looking within the alembic from which their own thoughts are distilled,

inspiration would spring from the solved mysteries, and they would know how life employs the potency of elemental matter in the creation of one's own mental universe.

What an interesting, important and vital function has been added to the great special physical phenomena? But to that small class to which Clerk-Maxwell made reference, all may be too easy and for them have a tendency to weaken the sublimity and inspiration of the conceptions of the divine drama of the universe into which they enmeshed their involved theories. But to those who have discovered that the splendors of the adornments of truth are due to their simplicity, and to her modesty, will come a deepening, a more impelling admiration of the grandeur of Nature, and the infinite wisdom of her Creator. Our Solar System, that favored alcove in the illimitable universe, should weary the tireless tongue in alone recounting the delights of the unlocked mysteries; and the pleasure of new sensations should thrill at the new conceptions of the silent, majestic procession of the planetary orbs, and from the knowledge of how the beneficent and dazzling splendor of the King of Day gently, with golden threads, restrains the heedless, inexperienced ardor of their youth, should come not only a better satisfaction but reinvigorated ambition to pursue the inviting conquest of Nature; then to hold the tension of the entranced senses, the reading out of the mysteries of the diamond-eyed guardians of the night, in one's own familiar language, should cheer and bless in that superlative degree, as do the voices and faces of home to the weary returning wanderer; and still diviner, turning his contemplation into the animation of his own personality, though the smallest, the sublimest universe of all,

the mystery of his own pulse, and the pleasure of his own ear will whisper the secrets of their own perception, and the fascination of his own eye shall know the alchemy of entrancing color; and finally when all of these have disclosed their occult potencies, and beholding the means and mechanism of thought itself, in its own marvelous citadel, will place the laurel on the brow of Rx as the Prince of Matter and the Messenger of Life.

CHAPTER VII

THERAPEUTIC APPLICATION

PATHOLOGY OF THE ATOMIC SCIENCE

OF necessity I must be the first pathologist of the atomic science, and it will not do to practice paronomasia for the facts, sense and application must be unmistakable, and rather consequences of the fundamental principles of health, more than of disease, and only incidentally as to remedies, where the principles have not already been tested and accepted as efficacious.

If there are no new understandings of health and disease, in the first place, there cannot be anything new in the pathology. I do not mean just the common understanding of health and sickness, but how does a body function in health and as definitely as possible how does it do so. The failures then would naturally be disease. But there are, at least, four new and vital concepts, material factors and fundamental principles that have not been known, although the functioning they have been doing has, of course, been known and dealt with pathologically.

Health and disease are conditions of something that is not now scientifically defined in the dictionary or the texts on physiology and hygiene, only inferentially, and because the four definite factors mentioned have no definite recognition. Therefore, this thing that I am writing about must be set forth and defined in the terms of the new factors to which the pathology must apply. Hence we must go back of health and disease to the concrete thing to which they apply.

The four new factors are, first, atoms and their inherent, cohesive and repellent energies, the dynamic forces that produce all of the phenomena; second, the New Law of Molecules, which employs exclusively the cohesive energy, and, third, the dynamic, inherent, repulsion energy of the new atomic element Rx, which, because of this repulsion and unequal distribution, in seeking an equilibrium, makes all the phenomena of cohesion possible, if not compulsory.

The fourth new fact and phenomenon, pathologically, is the most important and significant, although only an understanding of the actual efforts, the modus operandi of the other three factors. This fourth is to know that the act and action of atoms cohering is the thing, heat. The act of holding atoms into molecules and molecules into forms and masses is the ever-present thing, heat. The fact of its universality, the very conditions and states of cold are compelling evidences that heat is cohesion energy acting. As a matter of new and practical knowledge there is no other so satisfactory and important to the doctor. For since its so recent a discovery it has emphasized, clarified and confirmed quite all of the phenomena that I have been so long investigating. How this truth is confirmed and impressed while watching the changes in color in tempering steel.

If there had been any doubts and questionable problems as to the accuracy and soundness of the atomic science, the biological and the physiological confirmations would remove all of them. Therefore, it is made clear at once that health and disease has reference to the functioning of organisms that are actuated and operated by these fundamental principles and that their processes and operation is known as physical life. There are two classes of these mechanical organisms, Vege-

table and Animal, that seemingly so widely different, employ the same identical physical principles.

Although I have defined physical life elsewhere as indicated by the new discoveries, the discovery of heat permits of a closer and more full understanding of both vegetable and animal life, and touches the border line of the metaphysical.

VEGETABLE LIFE

Vegetable life is the continuous, single cycle of cohesive-action (known as heat) of atoms and the Law of Molecules, by which, from a miniature in a single seed, a specific form of functioning parts is produced, culminating in the production of one or more miniatures in seeds for repeating the cycle under like conditions.

ANIMAL LIFE

Animal life is a natural union and co-ordination of natural cycles of material laws by which the vegetable cycle is made optionally continuous by the cycles of circulation and the dynamic energy of Rx (the nervous force), by observing the natural laws which govern in all the cycles.

Thus we see that while vegetable life is contingent upon opportunity, animal life, while functioning under the same principles, being endowed with intelligence and initiating force, steps in above and can limitedly control nature, but must conform to the laws by which, not only the vegetable, but all the cycles function. We can now understand the definitions of health and disease in these new concrete terms.

HEALTH

Health is the normal cohesive heat action of the atoms and molecules of the body whereby the vegetable,

circulatory and nervous cycles are maintained in maximum condition for their harmonious interactions.

DISEASE

Disease is an interruption of the normal cohesive heat action of the molecules in some part of the body (from various causes) which affects the normal functioning of the other cycles by which the cohesive cycle is restored or the mechanism destroyed.

Therefore, the vegetable cycle controls both health and disease, while the other cycle may be the immediate or remote cause of the disease. While disease is always in the vegetable cycle, the cause is from the other cycles, almost wholly. It is capable of the greatest latitude of the cycles, for while it depends upon the proper kinds and amounts of atomic material and potential heat (Rx) to function, with lack and fearful excess, it does somehow function amazingly. The provisions for this latitude are the wisest in the economy of life.

A cold is not a disease, but checking of the cohesive heat action by the dynamic cycle of an excess or lack of Rx as from a draft, interrupting the circulation, causing accumulation of material, swelling, etc., and unrelieved will result in some disease of the tissue.

To be a little specific, the membranes of the throat and nose are glandular, and excretionary by evaporation. Cold, damp air checks the normal, and the same results follow as above. The nose runs and phlegm collects in the throat, croup, and when the phlegm is not thrown off by the lungs, pneumonia follows, which is so dangerous for the double need of removing the phlegm, and affecting the lungs' functioning.

Now this cycle is affected by foreign atoms in the blood with a similar effect upon the cohesive heat

action. And without a lengthy discussion and illustrations it will readily be seen by all doctors that infectious and contagious diseases are so many different, mild and drastic causes of affecting the cohesive atomic action upon which life hinges.

It may be noted that "cells" have not entered into the discussion, which is for the same reason, arteries, veins and nerves have not been used, because they are not essentially functional. The first requisite for matter is that it have form and occupy space. Just so the first requisite of the body it must have form through which and upon which the forces can function. Cells furnish the structure and tissue of the body and they are so built together that they furnish the two great essentials of receptacles for solutions and canals for their circulation. Taking the egg as a typical cell (while it is a vast aggregation of systematized cells) some have conceived the earth as a huge cell womb of created things. The interesting and entertaining feature of most lectures in biology are the picturesque, marvelous and numerous tissue-cells, and cells shown by the graphic illustrations. The former from life, and the latter largely from the concepts of the biologist. This marvel and variety of cell tissue is due to the difference of every molecule which must construct a different cell, for the molecule and not the cell is the functioning agency.

To be sure, there are differences in the natures of the cells, but these are due to the molecules of which they are composed and not to the cells themselves. The importance and marvel of the molecule is made impressive by the rows of colorless and colored liquids on the apothecary's shelves by considering they are all different and all molecular. Germs, bacilli, bacteria, animal-

cula, are themes, but not essential at this juncture and I will note in closing the wonders of the blood, the Treasury of Life.

THE BLOOD

The blood is a saturated solution of atomic and molecular materials for supplying the capillaries and receiving from them depleted material to be rejuvenated in the lungs. Its circulation is a true "river of life" for the body through which it keeps flowing is alive. Rx as the potential of heat is clearly shown in the scarlet arterial and the dark red venous blood. The former has been warmed and refined by Rx in the lungs into pure blood with a high tension, while the latter is more a mixture of materials, not necessarily impure but lacking in the functioning condition of the arterial.

The continuous urge to express one's own opinion has been a task for me to control and confine myself to the because, and here I may not succeed. For the blood is something more than a solution, there is something of personality to a molecule, just as there are ninety-three individual atoms, single and separate characters. Hence H_2O are alike, the same everywhere and forever. According to the Law of Molecules each part of the body has a model molecule for that part. And it does appear that there is a special blood molecule with its destructive office. Or that there are two somehow co-related, the white and yellow corpuscle. That they not only carry atomic material to the different parts of the body, but have some part and purpose in preparing, delivering and placing it in the permanent structure. It is evident that they are too large for osmosis, for the capillaries would soon deliver them to

the surface. They seem not only to deliver new prepared material for the demands of each special part, but to gather up unused and unprepared material, and have it revamped in the lungs. Hence to me their personality is most impressive. And among the corpuscles there may be individual kinds that function for special tissues, which is the closest to pure speculation. But this and the individuality of the corpuscles, may have to do with heredity, one of the perplexing problems of descent. Yet there is some support for this view from the reversion of fruit and flowers to the original ancestor.

If the blood itself is not wholly immune from disease, it is the least susceptible and even leprosy is not likely a blood disease. Venous blood is not, as elsewhere stated, impure. If there is any impurity in the blood it must also be in the arterial.

Rx is the life of the atmosphere. It produces it and then sustains it. Rx is the chief factor and force in the nervous cycle and neither of the others can get on without Rx. There is one thing sure, Rx is immune from all disease for it is the most skillful and active agent in curing all diseases, impurities and promoting health. Hence there is no pathology for Rx. In all of these discussions, mainly of causes, whys and hows under the general topics of Pathology, the pathology must be deduced from the answers to these. If a draft at one time causes a stiff neck and at another time does not, while it may be even a stronger draft, the reason is to be found in the "neck." For the condition of the system largly governs immunity.

In what follows in the progressive alignment and application of the physical factors and phenomena as considered in the light of the new fundamentals of the

atomic science, the pathology must also be deduced, as I do not attempt to make practical applications.

It must be evident from the first statement as to the "first pathologist" that this is a new and practical test to me of the new principles, and I must say encourages me as to the value as well as confirming the new discoveries.

RX AND REPULSION

In depicting the therapeutic value of the new developments of the Atomic Science, the most advious, prominent and continuous factors are Rx and its inherent repulsion energy, because atomic repulsion has never before appeared in the explanation of physical phenomena. This fact alone is sufficient to require an entirely new name, and especially since this newly discovered atom Rx, is the only atom in which repulsion functions. Therefore, it must of necessity be concomitant with quite all phenomena.

Rx is weightless, imponderable, but this must be explained, for all atoms are weightless, because weight is a force, which is produced by the cohesive energy of other atoms for Rx as explained in gravity or gravitation. Therefore, since Rx has repulsion instead of cohesion for its own atoms it cannot have weight. Therefore weight is not even a property but a condition. This is proven by present science, when it contends that a pound of gold on the earth would weigh 27 pounds on the sun. However, the new science explains weight by atomic action and not by the sizes of other bodies entirely, for size is only an arbitrary factor. Size or mass is a comparison on the earth, which is one vast uniform gravitational field, with equal radiation of Rx everywhere. And has not been proven outside of the

earth. For in the New Physical Philosophy I produce two pages of some thirty summaries from astronomical, measured data, that prove that the sun's attraction varies from Mercury to Neptune, and in a similar manner and amount between the planets and their satellites.

This is all very germane to the subject, and I have taken extra care not to misrepresent science and must here quote Professor R. K. Duncan in his "The New Knowledge":

"Science is naive; she takes things as they come, and rests content with some such practical definition as will differentiate matter from all other forms of non-matter. This may be done, strictly provisionally in this place, by defining matter as that which occupies space and possess weight."

This "naive" way of "taking things as they come," is for the purpose of supporting the "hypothetical Ether," which is here concealed in "matter from non-matter," for before the close of the quotation he says: "Matter is that which occupies space." Now, unoccupied space is void, nothing. The first and only fundamental fact that matter offers man to know what is is, is form, real essence, substance that occupies some space. Hence, if the "Ether" exists it must be matter.

Now with this one fact the Atomic Science starts, and discovers first that mass matter is an aggregation of the smallest part of each kind of matter that exists alone and occupies the least space and named an atom. Second, that mass is these atoms cohered together uniting their spaces by cohering to one kind of these atoms, named Rx atoms, which repel one another. These two things are all and the only things these atoms, or matter, does. Now in the cohering and repelling of Rx and ninety-two other kinds of matter, we experience

with matter, cohesion, repulsion, attraction, heat, light, color, weight, capillarity, electricity, magnetism, chemical-affinity—all phenomena of matter. Therefore, weight is no more a possession of matter than any other phenomenon, and that all of them are the acts of cohering and repelling, the bases of the Atomic Science.

ATOMS AND COHESION

When it comes to an erudite consideration of the therapeutic value of the new science the cohesion of atoms is as ubiquitous and important as Rx and its repulsion, which will become more and more evident as the reader better understands the new factors and their functions in the atomic science.

For cohesion is the inherent energy of every atom to cohere whenever it comes into contact with Rx. The peculiar and remarkable economy of nature is, why the cohesion for Rx only? which I have already purposely explained. But the same query applies to the repulsion of Rx, both of which are solved by the inscrutable economy of nature. For, when most minutely scrutinized we find them *all-sufficient* and can devise *no* other ways.

The atomic science greatly simplifies the human task of understanding the facts of the phenomena that pertain to human existence and entertainment. For there are only two Energies to know: the Cohesion of every atom for Rx, and Repulsion of Rx atoms for each other. All the forces of nature result from these two inherent attributes of matter and which produce all the properties of matter. For properties are conditions of mass while these two attributes are inherent in the atom. Properties are variable, while the attributes are unalterable. What a wide variation in the tenacity of iron,

yet in every degree the cohesion was maximum for that condition and arrangement of the atoms of iron. This is proven by the fact that the maximum strength of a bar of iron is at a definite temperature, for above and below this degree there is less or more Rx in the bar. This is also true of the human body for when too warm or too cold the strength and efficiency is less.

I stress this point of the presence of Rx, for I asked a prejudiced party for a criticism and he said: "Oh, too much Rx." I was satisfied, as I saw that he had not comprehended Rx, and was therefore imperfectly posted. For there are only the two factors, Cohesion and Repulsion, and there is not a single phenomena in which both do not function. The only place where Rx is alone is while on its way from the sun or any direct source of light. I do not object to prejudice, it is essential and the basis of personality and it injures the individual when he does not accept facts to improve his personality. Hence, if the facts of the atomic science cannot withstand all investigation, they are not facts and have no claim for recognition.

Therefore, the therapeutic efforts commence with these two fundamental facts that atoms are the foundation of molecules and mass, and that these two depend upon the atoms to cohere. Then the third thing follows that this cohesion is for Rx, and, therefore, in every molecule and mass, there is Rx as the cement to which each atom coheres. Then the fourth very great fact is that the repulsion of Rx results in the four states of matter, and that the new fourth state is this Rx when alone as light, atmospheric magnetism and sustaining the air and all gases.

Therefore, Rx might become irksome to some without the understanding that it merely represents repul-

sion, while all other atoms, wherever they function, represent cohesion, and there are so many different kinds of atoms, and Rx must be in the limelight because it does enjoy the monopoly of repulsion. This introduction of Repulsion, co-equal with Cohesion, and as venerable as the universe, into science is all-sufficient cause for the name the New Atomic Science.

ENERGIES AND FORCES

Energy and force have been fully set forth in the text but it will be helpful to touch upon them in a summary. There are only the two energies, Cohesion and Repulsion. They produce all the forces there are which display the phenomena of nature. Cohesion alone sustains the form and structure of the body, while Repulsion with the use of the cohesion of the atoms maintains all the life functions; the circulation of the blood and the nervous force, the chief function of which is maintaining the breath, which has a special treatment later.

Since the life functions are so evident and important it requires no argument to point out how important and illuminating is the discovery of Rx and its atomic repulsion. The nervous force has been only the "nervous force," a force that concerns the nerves from which it derives its name. Now we know that it is Rx atoms repelled over the nerves by the repulsion of Rx atoms for one another and that they are conducted over the nerves by the cohesion of the atoms of the nerves. Hence, both energies are essential in normal functioning. Then it is readily seen that, since Rx is individual in this process, if there is any trouble over the route that it must be in the nerves or their insulations.

Perhaps the most important, certainly the most satisfactory, knowledge from the discovery of just what

the nervous force is, is the fact that after every voluntary and involuntary action of the force some Rx is delivered as potential heat, and the mystery of the temperature of the body is solved.

This discloses the science of so many remarkable fetes of the human body with temperatures. Physiology asks how can the body maintain its proper temperature in air that is hotter and then explains it quite properly by the principle of evaporation, perspiration. But this is not a complete understanding. It requires to be known that the nerves regulate a constant supply of Rx the potential, and the external heat cannot enter the body by conduction as readily as in non-electrically equipped bodies. Then the new understanding meets the opposite condition of extreme cold, and why the lungs do not freeze from a constant stream of zero air.

A case is on record of man remaining ten minutes in a dry, hot-air bath, at 284°, seventy-two degrees above boiling water. But Eskimos live for weeks in air 175° below this blood temperature, 108° below freezing.

Of no less importance is the understanding of the cause of the temperature of infants, the crucial period of life when they are wholly dependent upon others.

ATOMS AND MOLECULES

There are two distinct applications of cohesion in the human body. The form and structure of the body is molecular and it is maintained by molecular cohesion, while the molecule is sustained by atomic cohesion.

We must understand that organic nature is based upon and governed by the molecule while the basis of matter and inorganic nature is the atom. Some may have considered water, because of its abundance as belonging to inorganic nature, while it is one of the most

persistent molecules of organic nature. That is why it is so abundant in animal tissue.

Each different part of the body is such because of its distinctive molecule, for the molecule determines the cell, and cells make up the tissue. Biology has been considering the cells as the factories of molecules, while the molecules build the cells. This is why the fruit of a graft is that of the graft and not of the root or trunk of the tree. Hence the office of the sap and blood is to supply atoms for the renewing and building of molecules.

The facts of biology show that atoms have their special forms and shapes. This is illustrated by N_2O, nitrous oxide, and NO, nitric oxide, for their shapes permit of these distinctive molecular structures and the two molecules have different properties. These facts pertain to the newly discovered Law of Molecules.

LAW OF MOLECULES

Had I been a professional instead of a lay biologist, the discovery of the Law of Molecules would naturally have had a general and royal reception, because it would have spread rapidly while it has spread only individually like heat by conduction as opposed to electrically. But it is sufficient to know that all pure and erudite biologists as well as all the lay hail every new discovery that tends to elucidate the mechanism and mysteries of the microscopic world.

The law is, that every organic molecule, when in a proper solution containing the free atoms of which it is composed, will continue to produce like molecules, build them into tissue, cells, or throw them off until the solution is depleted of some atom.

The chapter on Molecules is for the purpose of

verifying this law. It is discussed here as showing the logical continuity of the atomic science. The biologist has had no tangible, workable force producing the changes and evolutions revealed by his microscope, when large enough to be discovered. The new atomic science not only supplies this force in the inherent repulsion energy of Rx, but Rx also becomes the cement, the binding force that builds atoms into molecules, and the molecules into structures. For this increase in equipment he only has to modify his conception of the function of the cell. But he is further compensated for this change by a new understanding of the structure of the cell.

Every different molecule has a different form and doubtless points of cohesion, for NO and NO_2, and CO and CO_2 are four different molecules with different properties, capacities; as nitric and nitrous oxide, and carbonic oxide and carbonic acid. Therefore, since every molecule has a different form they must construct different cells, and the same inherent principles that construct the molecule govern in the cell constructing tissues. Hence, cells are not for the purpose of manufacturing molecules, but their two chief purposes are: first to construct some specific form of mass matter, and second, to provide receptacles to contain and convey sap in which are the atoms for molecules to build with.

By the present concept of the cells, all cells would be continually building molecules. This would over-do the quantity of molecules as is the case with lacteal glands, besides most molecules could not be conducted on by osmosis. Hence we see that this law of molecules works only where there is room for the additional building of cells which is usually at the surface. This, too, is slightly modified in the case of glands whose

molecules are for another purpose than building tissue; as, for instance, the gastric molecules are for the purpose of preparing the atomic solution.

In all these processes we see the need of some present force to keep them in operation and right here is the erudite argument for Rx. In the case of vegetation, Rx must be supplied from some external source which is all so well known that I need not repeat. But in the case of animal digestion in addition to the Rx supplied from the nervous force and external heat, in the process of digestion Rx is released from cohesion and from its repellent nature flows to an equilibrium and is utilized as the chemical-affinity of atoms. It is like the galvanic battery or chemical electricity, for when Rx is released by chemical action, better conductors are provided which lead Rx away in currents before the natural processes are attained.

Therefore, it is still more and more apparent that the atomic repulsion is co-equal in importance in the economy of nature with cohesion, and that the energy for each is contained in the atoms and is not some unknown extraneous force.

HEAT

Next to the discovery of Rx and atomic repulsion, as therapeutic knowledge of great value, is the discovery of just what heat is. This is at once evident from the fact that temperature is one of the first indications of an abnormal condition, either locally or as the temperature of the whole body. Therefore, the doctor knows that the normal rate of cohesive action is interrupted. This was known before by the person being sick, but did not know that it was the disturbance of the atomic or molecular cohesion of the system. In

some cases it may reveal the cause more accurately than now, but it will open up new and more ways for restoring the normal condition.

Fever is generally the first indication that there is something wrong somewhere with the metabolism of the body, and metabolism is illuminated by knowing that the action of cohering is heat, and that heat action determines the two processes of growth and depletion, anabolism the normal assimilation of food in growth and the supply of force, and catabolism the loss of tissue and force.

In this department of therapathy the knowledge of the agency and the processes taking place should be of no small satisfaction, while it may lead more directly to remedial treatments. The limits of temperature are final proofs that heat is simply the cohesion of atom in action.

Since Rx is the potential of heat it provides more means of restoring the normal condition. And since the nerves are the means for providing for heat action it explains the why certain electrical applications are beneficial and why others are not, and these reveal the fact that the doctor should be well informed in electrical currents. Until the discovery of electricity the only resource for restoring normal action was through medicine that affected the material structure of the molecules. This was accomplished not solely with medicine, but by the diet, for the blood is the chief source for maintaining and correcting the abnormal conditions of the molecules. For since the structure of the anatomy is molecular, disease is an abnormal condition of molecules, and hence diet must always remain a chief factor in maintaining and restoring a normal functioning of the whole body.

The sensations of temperature are the most evident proofs that heat is the cohesive energy of the atoms, in action. It is the most definite and personal evidence of the exactness of the new discoveries, while they are confirmed by all the physical tests for establishing new physical facts.

The beneficial effect of light has always been known, but now it is illuminating to know why it is beneficial and injurious as well. Heat is essential to vegetable and animal growth and we can now see why sunlight is the best way of supplying Rx for this purpose, because of its uniformity and evenness of application, for light and the electric current are pure atomic conditions of Rx, the potential of cohesive atomic action; the former the separated, independent atoms, while the latter is Rx mass with all of the atoms in repellent action with its neighbor.

It is now seen that every therapeutic effort, whether of light, electricity, heat, manipulation, or medicine, has to do with some heat action. The cohesive action is increased by additional Rx and decreased by the withdrawing of Rx. It is not so evident in the case of medicine as in the others, but the effect of drugs confirms the declaration; for in the first place the atoms and molecules of the drug have a direct effect upon the nerves and they govern the supply and conduction of Rx. In the case of soda to relieve a sour stomach the proposition holds true. The acid condition is abnormal and injurious cohesive action. The chemical action that results from the molecules of soda restores normal cohesive functioning of the chemical processes in converting the food into chyme, and the whole operation is the cohesive action of atoms and molecules, and the act of cohering is heat.

In the multifarious processes of therapeutics it was never before supposed that heat was in every one of them and in most of them the most important.

The whole process of digestion is a complete confirmation of the discovery of heat, supply new concepts of the nature of atoms and the importance of molecules. The temperature shows that in addition to the cohesive strength of the molecules, that a definite amount of Rx, potential heat, is essential to break down the molecular cohesion of the class of substances known as foods. For they must be placed in atomic conditions in order to produce the special molecules required in normal blood, the corpuscles, and the marked phenomenon of the change in color of the blood is evidence of the changes in cohesive tension, which determines color, which tension is due to either the addition or subtraction of some element.

To anticipate those posted in the changes in color in tempering steel, who may think that the last statement does not hold, I must add that the whole process is one of the strongest confirmations that Rx is matter, an atomic element. For Rx (heat) was put into the steel and went through the process of producing violet, indigo, blue, green, yellow, orange, red, white, and as Rx is taken out by cooling, the reverse order of colors is obtained. Now this cannot be explained by the "molecular hypothesis theory" of heat without several hypotheses, besides furnishing no logical clues as to what light is, besides the one insurmountable hypothesis of an unknown, unprovable element the "Ether," in place of Rx, which has more proofs of its reality than gold or oxygen.

If anyone wishes to get rid of the concept of this late "electron-atom" as a constituent part of an atom of

nature, it may easily and readily be done by trying to account for cohesion of mites with incredible velocities and impossible orbits. It cannot be done without violating all of the fundamental laws of physics. And then to have the exultant, exhilarating conviction of complete freedom, try to account for this universal and crowning force of heat. For this new concept fits so scientifically, so harmoniously, so mentally refreshingly into all the phenomena of the great essentials, that no other fact of nature seems so assured and potential.

This discovery of heat is so illuminating that my pencil loses all discretion as to stopping. It is so enthused that it would start out with the tripod, triumvirate, of atoms, cohesion and repulsion to explain the material universe, and I can find no advice to restrain it, for the most important, vital, universal and continuous action would be cohering.

LIGHT

Light actually illuminates the therapeutic value of heat; and the discovery of just what heat is, illuminates the cause of the curative value of light. Light is pure Rx. It is the chemist's c.p. Rx, and Rx is the potential of heat. For Rx and atoms are essential concomitants of every display of heat, and the display is a revelation of the nature of atoms.

Since light is atomic Rx the quantity of light must be the quantity of Rx employed. And since color is the velocity of the Rx of the different colors they determine the way it is delivered. Bright sunlight burns and blisters more because of its velocity than quantity. The very principle of light verifies this for it is the momentum of the mite Rx that drives it through the cornea of the human eye. But this is also elsewhere

proven by photography. For while the film is in the dark it is bombarded by Rx, but with the same tension as the Rx on the surface of the film which is therefore not disturbed. But when light is admitted Rx breaks through the Rx on the film and chemical action takes place. This also proves that colors are velocities, for the film is differently affected by the light from white and dark objects. From these facts follow the beneficial and harmful effects of light, by which their therapeutic value may be determined.

There is no question as to the curative properties of light, in fact, the injurious effects are themselves a proof. And proper sunlight and daylight are universal evidences. There are extremes in all cases. Physiological laws are just as inevitable as physical which they are, applied in quantities and combinations in the living human organism. The marvel of the mechanism and the means provided for keeping them in harmonious order and correcting disorders by the failures that do take place, are inexplicable without some design. In this particular is found those pertaining to light.

LIFE

Vegetable life (broadly defined) is a single cycle of the combined and harmonious working of the laws of cohesion, repulsion, the law of molecules and capillary attraction, from a given starting of the material mechanism in the seed, or germ, until a complete cycle culminates in another seed.

Leaving the connecting links, or differentiations, higher animal life is a combination of cycles. Employing the vegetable cycle, it uses the mechanical cycles of circulation, respiration and nervous action to make the vegetable cycle continuous for greater periods.

Now in the vegetable cycle the actuating force, capillarity, which is so obviously seen, is Rx, requires a continuous and a stated (without limits) supply of Rx, and the most perfect comes from light, which is applied directly, but is chiefly stored as heat, whence it is doled out in the wonderful conduction of heat to supply chemical action and molecular cohesion. Blight or disease is due to interruptions in some one or more of the cycles by the lack or excess of some element or the lack and excess of the supply of the motive force, Rx. Hence how self-evident is the function and phenomena of light in the perfect processes of life, and how evident that the most efficient agency for keeping and restoring the processes to normal is by means of light. The therapeutic value of light, therefore, depends solely upon the wisdom in knowing and using the proper kinds. And since quantity is the controlling factor, how evidently it proves that colors represent velocities which largely determines quantity. On general principles light is a constant and continuous factor in functioning of the life cycles and its effects are everywhere evident in both vegetable and animal life.

The influence of light must have been one of the first discoveries of primitive man, and ancient history records that sun-baths were generally employed for retaining health. Pliny, the younger, records that his uncle, Pliny the elder, an admiral of the Roman fleet at Misenum, had just taken a sun-bath in the afternoon of August 24, 79, as the eruption of Vesuvius broke over Pompeii, in which he perished. It is recorded that potatoes have sprouted slowly and failed to sprout under the same condition, except that of sunlight. Also tadpoles have failed to develop deprived of light; and some have remained stationary for four

months without light, and then developed into frogs in fifteen days with favorable light.

These support the contention, in "The Law of Molecules," of the necessity of Rx in the seed to start germination. Therefore, this beneficial effect of light is forceful evidence for the therapeutic value of Rx in the form of light which embraces color.

In the anatomy of the human mechanism the greatest principle is cohesion, which is the fundamental principle of mites of matter and the magnitudes. And when the physiology of the organism is considered the controlling and most vital principle is cohesion, heat, this energy of matter; and the most abundant source of the potential of heat is Rx in the state of light. Not only the source but one of the most efficient is daylight which is a special condition, produced by atmospheric Rx, for we have discovered that luminosity is the air. Without bright daylight vegetation does not attain its natural coloring.

Hence, with this knowledge of Rx in the essential functions of organic nature it is self-evident that there must be great therapeutic value in the scientific application of light to the human body. I say scientific because the wonderful refinement of the harmonious operations of the cycles of animal life is not only evident in perfect health but in the universal constancy of the temperature of 98.6°.

ELECTRICITY

In my The New Physical Philosophy, published in 1913, I call attention to the therapeutic value of electricity, and also to the dangers of unscientific applications, because of its maximum concentration of Rx. I had not then discovered just what heat is, but was very

close to the discovery, for in that work I say, "Heat is the action of Rx and atoms or molecules of matter whereby the quantity of Rx in a body is increased or diminished." But I must confess that I did not then know, and did not until the real discovery in November, 1924.

The various currents of electricity are the different means for supplying Rx to the body, and vary just as do the different kinds of light. However, there is a wider difference regarding their production. For light is a natural product however secured, by the incandescence of matter, while electricity is an artificial product, or condition, and now the chief means of securing light. It is rather, as secured and employed by man, an artificial manner of harvesting Rx which is the potential of heat which is the source of light.

Owing to the many kinds of electrical currents there are the various means of using Rx therapeutically. It affords more ways than there are for restoring some depleted element to the body. The marked difference of chemical and dynamic currents is very evident, for the former is a flow by atomic contact while the latter is like a projectile force.

On general principles there can be no doubt of the therapeutic value and possibilities of electrical currents but the various currents have to be known by experiment and understood by the doctor just as the nature and effects of medicines. And the measurement of "doses" are quite as essential.

High frequency electric currents are homeopathic methods of applying a dangerous quantity of Rx in the ordinary electric current. The same mistake was made in understanding high frequency currents, as was made

in supposing that there were more vibrations in a violet than a red color, that the violet and high frequency were of greater potential. The former was the cause of the latter mistake. Colors are velocities and are proven by every test and effect of the colors. But it will be easy for electrical experts to correct the mistake in high frequency.

But it needs to be explained that the violet of the prism and of X-ray tubes are not the same, as is now the belief and treatment. The X-ray violet has a larger quantity of Rx with a greater velocity and this is what produces its color while the extra Rx contributes to its danger. The violet of the prism has the least Rx of the spectrum and the slowest velocity. Because the violet and the ultra-violet had the active effect, it was erroneously supposed that there was some special potential properties in the rays, which is not true. A photograph can be taken by a magnet. No, they are all Rx atoms and it is only the manner of manipulating them that the various effects are secured.

It is known that the circuit current is deadly. Why? Because of being a continuous stream of Rx with great velocity. Therefore, the briefest touch of that current would overcharge the body. Hence this solid current is broken up by the electrical machine into small quantities passing between the sparks or breaks in the solid current, produced by the "buzzer" or oscillations in vacuum tubes.

Rx is of such a nature and for its purpose must be used on the spot and at the instant of its presence. Vegetation can retain daily only that quantity of Rx, received from sunlight and the air, that can be used in building molecules with atoms from the sap, and building the molecules into cohered, increased structure. It

is this quantity that makes vegetable tissue combustible. Hence, the storage of sunlight in the carboniferous age is something more than scientific fiction. But it was *mere* fiction, however, when it was discovered as stored motion, a pet phrase is a rhetorical display.

Great progress has already been made in the use of the electric current, but greater will now be made by knowing that electricity is not only the maximum or mass volume of Rx in motion, but that Rx is the nervous force, and chiefest of all, that Rx is the cement of the human anatomy, because the cohesive action of atoms on Rx atoms maintains the form and structure of the parts of the body. Hence the problems of the therapeutic uses of the electric current for specific conditions; for if a certain current passed in a certain direction is curative the opposite direction might even prove harmful.

There is undoubtedly a current and application that will relieve lockjaw, and restore life that has suddenly stopped from shock. As I have shown elsewhere, the atmosphere is the most wonderful and vital phenomena known to man, and that while being the most essential is the most dangerous. It is Rx that maintains the atmosphere from which the lungs collect Rx and divert it into currents over the nerves which constitute the nervous electrical force, which is the dynamic force that operates and controls all the functions of the human body. And the functions of the body require a constant supply, for in nature, forces go straight on and do not anywhere vibrate, as is so erroneously supposed. Hence as this supply is received in the lungs, it performs the physical functions in its passage and then escapes from the surface as the aura of the body. If anyone has been skeptical as to the reality and essential-

ness of Rx these known and personal facts should remove all doubt.

All energy and force must be in and manifest by matter, for all else is void, and by its manifestations Rx is the most evident and best known of all atomic matter. Seeing and feeling are considered fundamental evidences of matter, and by these tests Rx is the only matter ever seen or felt, but the one fact that it is only one layer deep on the surface of all other matter has concealed the tremendous fact from the beginning of knowledge. It is the Rx on the surface of every object that reflects light Rx, for if it were not, the cohesion for Rx would absorb all light. Therefore it is virtually only the Rx on the surface of every object that we do see. Rx is on the surface of the green and yellow oranges, but it is held by a different tension on each. Hence, when white light is reflected from the yellow orange the greater tension of the surface Rx reduces the reflected Rx only to 175,000 miles per second, but the looser tension of Rx on the green orange reduces the velocity to 170,000 miles, the velocity of green light.

Color is such a characteristic property of all objects and especially substances, that it seems to be a definite part rather than a condition that affects light. It seems to be a part and that light, a something else, a distinct thing, reveals that color, while the color is the thing, light itself, and no part of the object. Daylight is necessary for color, and color indicates the effect of objects on that light. Now gold and brass have nearly the same effect, hence it often requires other tests to determine.

With the advent of electricity we come to another understanding of Rx on the surface for when it is put into motion it becomes electricity. The surface Rx

does become electricity Rx, while in the case of light it merely affects light.

These facts are sufficient to prove that Rx is the great therapeutic agent, and that light and electricity are means for its use.

MAGNETISM

While most of what has been said of electricity applies to magnetism, there are features of magnetism that are special to this phenomenon. The aura of the body partakes of the nature of atmospheric magnetism. Rx is radiated from the body with increased velocity and additional Rx thrown into the air. This can be recognized as heat radiation with a precision resistance thermometer (potentiometer).

The facial effect of individuals is largely magnetic and especially from the eyes, although it is modified by other conditions peculiar to the individual. The effect of touch is more electrical.

The magnetic influence of the earth is undoubtedly effective on the body to a very limited degree, for the bodily functions are continual and are effected by the electrical currents over the nervous system. In the case of sleeping, too little or too much covering, conditions of the air, have effects that are so much greater that the magnetic effect is modified.

Gravitation is a force that has its influence upon all the functionings of the body, but it is so constant and ever present that it has governed in the stabilizing of all the functions. It is so evident in governing the time food will remain in the stomach in sleeping on the right or left side.

It may be that there are curative effects from the proper administering of permanent or electro magnets.

All cases of pain and sickness are due to some molecular disorder, except the pain caused directly by action upon a nerve. Pain and pleasure are one and the same thing, action upon the nerves that effects the continuous cohesive action of the molecules concerned. The degrees are what determine pain and pleasure.

MEDICINE

I must upfill this osier cage of ours
With baleful weeds and precious-juiced flowers.
The earth that's nature's mother is her tomb;
What is her burying grave that is her womb.
And from her womb children of diverse kind
We sucking on her natural bosom find,
Many for many virtues excellent,
None but for some, yet all different.
O, nickle is the powerful grace that lies
In herbs, plants, stones, and all their qualities;
For naught so vile that on the earth doth live,
But to the earth some special good doth give;
Nor ought so good, but, strained from their fair use,
Revolt from its true birth, stumbling on abuse.
Virtue itself turns vice, being misapplied
And vice sometimes by action dignified.
Within the rind of this small flower
Poison hath residence, and medicine power:
For this being smelt, with that part cheers each part,
Being tasted, slays all senses with the heart.
Two such opposing kings encamp them still
In man as well as herbs,—Grace and good Will;
And where the worser is predominant,
Full soon the canker death eats up that plant.

—*Shakespeare.*

Dr. Friar Lawrence's panygeric on the medicinal capacity of nature, is so apropos to the new concepts from the beginning to the close, that I could not find a suitable place for a period. It discloses, too, that the

Friar is a chemist and philosopher no less than a genius in poetry.

I cannot here make the applications even if they could be framed in words. But when one becomes a regular in the new atomic principle, a pictured or contemplated comparison will be as pleasing as the harmony of the poetic strains.

The Atomic Science commends itself in that it not only discloses, defines and locates the forces employed in therapathy, but the material elements that constitute the living organism. And it reveals that the forces do not exist apart from the elements. This is no small part of the new physics, for nearly all the forces have been considered and are now generally considered as some mysterious energy and agency wholly independent of the matter concerned. And doubtless, were it not for the actual discovery and proof of heat, many could not bring themselves to believe this is true.

Therefore, the science of medicine is established. But at the same time, medicine cannot, and never has, ignored the direct application of the forces in disease, for it is expert in the application of heat, which is the chief of the forces.

Nor can it be claimed that any use of the forces is a universal panacea, the total of any pathology. The laws of health apply to the sick and the well. The causes of disease are not confined to the abuse of the material but to the forces. Too much light, heat, electricity, magnetism, motion or manipulation have their effects that require remedial measures to restore. The medical profession has been unduly alarmed over the discoveries of osteopathy, chiropractic, chromo, electrotherapeutics, etc., etc. These fields should, instead, be studied, their actual merit or demerit could then the

better be determined. Surgery has its usefulness, but is useless in a case of smallpox or typhoid. And every branch of therapeutics employs medicine, for food is a medicine and should be the chief factor with the healing profession from the beginning of materia medica.

For the proper functioning of the chemistry of the body nature has provided three grand classes of chemicals, albuminoides, fats and oils and saccharine substance. The inscrutable laboratory of the stomach takes proper proportions of these, even supplied in such indifferent ways and amounts, and manufacture the vital blood stream of life. But a lack of one or undue proportions continued, do affect the health and strength of the body. A blood long changed in its proper consistency has its effect upon first the glandular structures and these first affect the blood itself before it does the rigid tissues. These facts are all chemical and is it not scientific that, besides returning to the proper proportions of foods that some medicines would have beneficial effects upon the disturbed natural chemical processes?

These deductions are confirmed by the new understandings of the blood, and how the temperature of the body is maintained at such an exact degree. This last, as elsewhere more fully shown, is due to the constant supply of Rx over the nerves which are proportional for the size of each body. The principle which governs in electric wiring.

There is some harmless scientific fiction that needs correcting, about oxygen in the lungs and blood; for now it is contended that temperature in each is due to combustion because of the presence of oxygen. I am not discrediting the importance of oxygen, but rather am explaining the real why of its importance.

The specific heats, as gravity, are determined by that of water. Now the specific heat of oxygen is .212 while that of hydrogen is 3.406, or sixteen times as great. We can now more reasonably see why oxygen is sixteen times heavier than hydrogen, for Rx has no weight and hence makes hydrogen sixteen times lighter than oxygen, taken in by the lungs.

A physiology gives dark venous blood as containing 8 per cent oxygen, 17.5 per cent carbonic acid (CO_2), and more water; and scarlet arterial blood as 18 per cent and 6 per cent, respectively, and less water. Hence there is the same quantity of oxygen in each, but in different forms. The same error occurs in inspired and expired air. The oxygen is the same but in different conditions.

But this scientific deduction, without some new facts, cannot be misunderstood yet it is exact. The blood is composed of a definite quantity of atoms from and in molecules, as it leaves the heart, scarlet in color. Now when it returns dark red venous blood it contains the same kind of atoms, and virtually the same in amount. The arterial gave up some of its atoms in building and renewing parts, and the (what we erroneously term) worn-out material that was replaced. Now this "worn-out" material are chemically pure atoms, but in different combinations. Hence, what makes the difference in color? It is the same principle elsewhere explained by the green and yellow orange. The scarlet blood has more Rx, the corpuscles have greater tension. In the circulation it is depleted of some Rx and atoms, worn-out loose molecules and the tension of the venous blood is weaker and reflects Rx with a lower velocity, that of dark red.

Oxygen is prominent among the atoms next to that of

Rx not because of its heat capacity but of its nature of cohering with so many other atoms, thus effecting so many more kinds of molecules. It does not contain or hold even an average quantity of Rx. H_2O are nearly the two extremes of capacity for Rx. The cohesive action is also slower than with hydrogen. This is what makes hydrogen such a violent explosive.

This bit of physiological chemistry with the new atomic element Rx is not a digression from the subject of medicine. It demontsrates that medicine is a fundamental principle in therapeutics, while it follows as essentially that, Rx the most important element of the whole 93, should be administered beneficially in some of its special and individual forms of light, electricity and heat, while Rx will ever remain the chief agent in diagnostics.

NERVOUS FORCE

Physiology tells all about nerves, nervous system, nerve sensation, but discloses no information of the force that functions throughout. It is designated solely as the "nervous force." Hundreds have named it electricity, but that is only another name, as no one explained the electricity. But the Atomic Science building up from its fundamentals, proves that force is a product of energy and that energy is the capacity to produce action or motion of matter, and that neither can be apart from matter. Then discovering there are only two energies, cohesion of atoms and repulsion of Rx, deduces that the nervous force is Rx, confined to the nerves by cohesion and that when Rx atoms act their action leads them over the nerves as the nervous force.

The nervous system is a special highly organized and

specialized electrical plant, and the currents over this system are voluntary and involuntary by some action upon the Rx of the conductors.

Thus the nervous system is a highly constructed and complicated instrument, played upon by the forces of nature, and the intelligence of man by the nervous force itself. The keys for the use of man are the special senses.

SIGHT

The new development regarding vision is the discovery that light is a material atom with specific velocities that impinge upon the retina of the eye. There is no doubt that vision is physiological, but the same problem that developed in the chapter "Seeing Space" appears regarding the color of objects, for all light is color and represents a definite velocity, and velocity is determined by the cohesion tension of Rx on each object.

The next new feature is that more than by perspective, distance is determined by the quantity of Rx received from the objects. This emphasizes more than colors even, the supreme delicateness, the finesse of mental perception. But the delicateness is wondrously shown by the distinction of shades, hues and tints, and specially enforced by those who are color blind. The oculist should be professionally interested in Rx and the delicateness of the mechanism of the eye, that all eyes should avail themselves of the experience of the oculist with Rx.

HEARING

Sound is more wonderful and complicated than light, the ear than the eye. For light is the simplest of all

phenomena, being solely Rx and velocity, while sound is Rx, velocity and molecules.

Some scientist said: "No one can study carefully the human hand and fail to be convinced of the existence of Deity." But Gailen said: "The mind and not the hand taught man the arts." But the study of the structure and offices of the eye and ear confirm Deity as the Creator of the mind which utilizes such supreme mechanism.

The greatest marvel of the ear is, that it measures distance in the dark. Yet the same explanation for distance with the eye is the only one that applies to the ear and quite confirms the explanation of distance as due to the quantity of Rx.

TASTE

The tongue is the special organ of taste which deals with the atomicity and structure of all matter and in a special way indicates the distinctive nature of each atom. That pure water is tasteless and the fact that substances must be dissolved to be tasted indicate that it depends more on the atom than on the molecule. But the fact that insoluable substances are tasteless is some evidence that taste may be intimately connected with the action of cohesion.

Since the substances tasted must be in solution, chemical action is required and we have the new key to chemical affinity in Rx and the other key is the cohesion of atoms.

SMELL

Smell has to do with the third state of matter. It is intimately related to the sense of taste, for many odors at the same time affect the sustatory nerve. Odors must

be dissolved the same as flavors. Odors are electron molecules, as has been explained in gases. That the odor molecule must be taken into solution, like taste, shows the chemical requirements of this sense.

The study of smell commences with the science of odors. What are they? They are due to the principle of evaporation. Volatile substances have a great affinity for Rx and as soon as a surface molecule is surcharged with Rx it is repelled from the mass and becomes a gas electron. Hence when they enter the nostrils they are prepared to enter actively into a solution because of their supply of Rx.

In reducing coal in retorts, in the manufacture of gas, many things are produced, the coke and coal tar, Co, CO_2, H_3N, S, CH_4, C_2H_4, while none of these substances exist in coal. The coal contained C, H, N, O, S, held in other combinations with R, and the excessive Rx in the heat, produced these different combinations in the retort, which, in the course of manufacture, they are separated and the gas retained. Then when the gas is burned another chemical action results from the elements in the air, and the most important and active principle is Rx. But when the gas electrons are taken into the nose, still another chemical process takes place, and the sense of smell designates it as odor. Thus Rx is the dominating factor in all of the senses.

TOUCH

The sense of touch has no special organ, yet is the most constant and universal of all the sensations and a final analysis reveals that it is the most essential as it is the basis of every other sense. It is the monitor of pain and pleasure. If all the senses are locked in sleep it is the first in administering to each. And strange enough,

while it is the sense that keeps awake, it is the sense that puts to sleep and makes of sleep a benediction. In short, the whole vast empire of physical provinces of the body is so united, by the nervous system, with the capital, the brain, that it is kept informed simultaneously of the exact state of commercial and social affairs in all of them.

The most constant sensation is that of temperature, and since my discovery of just what heat is, this sensation, it seems to me, is the absolute proof of the correctness of the discovery. For this constant sensation can come from no other source than the cohesive action of atoms and molecules for Rx which is continually passing through the system. The subject is too large to attempt any detail and the main problem is, What is sensation? and what are its two extremes, pain and pleasure? We will try to sustain the new understanding.

Pain. Physiology asks, "What then is *pain?*" and then concludes its investigation with this answer: "Pain must, therefore, be a modification of the general sensibility which follows an excessive degree of excitement of the nerves, there being a natural limit to the amount of stimulation which they will sustain." That is very good when we consider that the physiologist did not know what "sensibility," "stimulation," nervous force are and had no knowledge of the existence of Rx. Yet it is not logical, because he says, "follows an excessive degree of excitement," as though it were a consequence, while it must be the real thing, because it is always there with the excitement.

Therefore pain is excessive cohesive action, at special locations in the body which is made manifest in the brain at the end of the connecting nerve by the arrival

of extra Rx, or Rx pressure. Pleasure is merely increased activity with additional cohesive action without more Rx, or since the terminal of the nerve is in the brain the accumulation of Rx without a natural outlet may occasion the pain or pleasure sensations.

Blushing is a natural consequence of this view, as the sudden increase of this action causes an electrical action that flows out to the ends of the nerves which must, from the very nature of Rx, do something, and that is stimulation of the blood in the capillaries. This is logical and essential, for when the mind moves a muscle it sends extra Rx to that muscle, cohesion must follow (from fundamental principles) the muscle contracts and motion or pressure result.

The structure of the skin is sufficient evidence of the correctness of this explanation of pain. For the cuticle conducts Rx through atomically to the terminals of the nerves, the papillæ of the cutis. Hence, Rx is thrown atomically into the electric, static of the nerves. Now when the skin is pricked by a pin or the exposed surface of the cutis touched a quantity, or virtually, a static current of the pin or touching instrument produces instantly the "excessive stimulation," the physiologist had in mind.

Numbness comes along to indorse this explanation, for numbness must be a quiescent state of Rx and the atoms. Rx is not moving, because of lack of nervous Rx, pressure over the nerves concerned.

How all of these explanations tend to confirm that heat is cohesion acting. Exercise brings excessive or extra Rx into the acting muscle and Rx is the potential of heat, and heat does follow. What an inspiring contemplation of the superlative wisdom in the provision of using Rx as the force to move a muscle and then

assume the greater function of warming the same muscle.

What a theme, the uses of touch. But I am debarred and can use only one illustration of the marvelous delicateness of touch, which confirms most of the above.

"Laura Bridgman, with neither sight, hearing nor smell, could detect the presence of a stranger in the room, without contact. Touch, with the other new facts, furnishes a scientific understanding. The aura of the body is radiated Rx and each has it own velocity of radiation and thus by the touch of radiated Rx she recognizes a new source. There is here some scientific foundation of some of the phenomena of telepathy; at least, a physical means, a radio, of communication. But the problem of placing it into form that conveys intelligence seems insuperable.

BREATH

Breath is the beginning and end of life. It is remarkable that the fourth, the last state of matter to be discovered, is the first of importance to human life. But it does not end there. This fourth state is the universal state for all the vital physical forces everywhere. Through it Rx visits from star to star and it is the state on which the universal force of gravitation depends. Light is this fourth state alone.

The babe is born with all the cycles of human life prepared to start; but it is not alive. But the action of the air sustaining Rx impinging the cilia of the lungs, start the current over the pneumogastric nerve, the nervous force is born, and all the cycles start, the babe is alive, a sentient being.

The atomic science has set the stage for a human drama. Commencing with the atom, cohesion and

repulsion it traces their multitudinous combinations into the marvelous mechanisms, the force that binds the parts into rigidity, and now the actuating force that moves in unison and harmony of all the cycles that minister to all the necessities of human existence.

But getting down to the problems in breathing we find wonderful confirmations. The inhaled air is cold and dry, the exhaled hot and moist. Whence this heat required for warming and evaporation? I have found no other explanation, but in this which requires more Rx, more heat potential; where does the extra Rx come from? This is a deep and serious problem, for the lungs take Rx out of the air. Here is another of the so numerous places, that I feel like waiting for the reader or a physiologist to answer before I do. In some cases I have suggested to the reader to stop and frame his own answer first, which should be of no little satisfaction to the reader.

Now the Rx taken from the air goes over the sensory fibers of the nerve to the gray matter of the medulla oblongata, replenishing the nervous force (currents of Rx). But it takes tremendous force to inhale another breath and Rx is sent over the motor fibers of the same nerve and moves the muscles. But when it has performed its cohesive action it is through or remains as heat. (We have shown exercise produces heat.) But we must take another breath for the same purpose, and send back Rx to move the muscle again. Hence, there is the Rx of the former action. Ah! and this is some of the extra Rx, the potential heat that warmed the breath and evaporated H_2O and other atoms, chief of which is C.

Now this marvelous process of supply and consumption is not confined alone to the lungs, but the whole

body, and the consumed or used Rx escapes as the aura. Therefore, we see that the lungs are wise and turn the aura into practical use as it bids the beneficent Rx a farewell, bon voyage, as it enters upon another useful labor of helping to maintain the gracious atmosphere.

CONCLUSION

Thus I have made applications and drawn conclusions from the facts, and have not used my opinion nor beliefs. The problem, therefore, as it now stands, is as to the verity of the facts. If they cannot be maintained the conclusions will be modified or destroyed. My confidence in the conclusions is greatly assured by the acceptance of the facts by so many qualified and acceptable judges. It is remarkable that such a number of the facts have been confirmed in practice and experiment by which they must all be confirmed.

All of these are the credentials the Atomic Science has to present to the public forum.

TABLE OF ATOMIC WEIGHTS

O-16.00

		(1910)[1]			(1910)[1]
Aluminum	Al	27.1	Molybdenum	Mo	96.0
Antimony	Sb	120.2	Neodymium	Nd	144.3
Argon	A	39.9	*Neon*	Ne	20.
Arsenic	As	74.96	Nickel	Ni	58.68
Barium	Ba	137.37	*Nitrogen*	N	14.01
Beryllium	Be	9.1	Osmium	Os	190.9
Bismuth	Bi	208.0	*Oxygen*	O	16.00
Boron	B	11.0	Palladium	Pd	106.7
Bromine	Br	79.92	*Phorphorus*	P	31.0
Cadmium	Cd	112.40	Platinum	Pt	195.0
Cæsium	Cs	132.81	Potassium	K	39.10
Calcium	Ca	40.09	Praseodymium	Pr	140.6
Carbon	C	12.00	*Radium*	Rd	226.4
Cerium	Ce	140.25	Rx	R	0.
Chlorine	Cl	35.46	Rhodium	Rh	102.9
Chromium	Cr	52.0	Rubidum	Rb	85.45
Cobalt	Co	58.97	Ruthenium	Ru	101.7
Columbium	Cb	93.5	*Samarium*	Sm	150.4
Copper	Cu	63.57	Scandium	Sc	44.1
Dysprosium	Dy	162.5	*Selenium*	Se	79.2
Erbium	Er	167.4	*Silicon*	Si	28.3
Europium	Eu	152.0	Silver	Ag	107.88
Fluorine	Fl	19.0	Sodium	Na	23.00
Gadolinium	Gd	157.3	Strontium	Sr	87.62
Gallium	Ga	69.9	*Sulphur*	S	32.07
Germanium	Ge	72.5	Tantalum	Ta	181.0
Glucinum	Gl	9.1	*Tellurium*	Te	127.5
Gold	Au	197.2	Terbium	Tb	159.2
Helium	He	4.0	Thallium	Tl	204.0
Hydrogen	H	1.008	Thorium	Th	232.42
Indium	In	114.8	Thulium	Tm	168.5
Iodine	I	126.92	Tin	Sn	119.0
Iridium	Ir	193.1	Titanium	Ti	48.1
Iron	Fe	55.85	Tungsten	W	184.0
Krypton	Kr	83.0	Uranium	U	238.5
Lanthanum	La	139.0	Vanadium	V	51.2
Lead	Pb	207.10	Xenon	Xe	130.7
Lithium	Li	7.00	Ytterbium	Yb	172.0
Lutecium	Lu	174.0	Yttrium	Y	89.0
Magnesium	Mg	24.32	Zinc	Zn	65.37
Manganese	Mn	54.93	Zirconium	Zr	90.6
Mercury	Hg	200.0			

NOTE—Names of metals are in roman, and non-metals in italics.

[1] International Committee on Atomic Weights, J. Am. Chem. Soc. 32, 3 (1910).

VOCABULARY

NOTE: All definitions are from standard text-books and Webster's International Dictionary.

A

ABSORPTION—Imbibition of one body by another.

ABSORPTION-SPECTRA — A spectrum showing black lines where colors have been absorbed by the transmitting medium.

ACCELERATOR—That which increases the speed.

ACETIC ACID—The acid of vinegar, $C_2H_4O_2$.

ACID—A class of substances having hydrogen as one of the essential constituents. The aqueous solution has a sour taste, and change the color of litmus from blue to red. When dissolved in water they conduct and are decomposed by an electric current. In aqueous solutions also their hydrogen is displaced by certain metals and is electro-negative.

ACIDITY—Power of a base to unite with one or more equivalents of an acid.

ACIDOSIS—Acid intoxication; caused by the production of an abnormal amount of acid in the body.

ACIDULATION—Making moderately acid.

ACROMEGALY—An abnormal development chiefly of the bones of the face and extremities.

ADRENAL—Gland near the kidneys.

ADRENALINE—Active principle of the suprarenal gland.

AFFERENT—Nerves which convey sensations from the external organs to the brain.

AGGLUTINATION—A process of union in the healing of wounds.

ALBUMIN—A proteid, animal or vegetable, which is soluble in water and coagulable by heat.

ALIMENTARY TRACT—The tube extending from the mouth to the anus.

ALKALI—An electro-positive substance combining with an acid to form a neutral salt, and having marked basic properties.

ALPHA-RAYS—Rays of relative low penetrating power emitted by radium and other radio-active substances, and shown to consist of positively charged particles (perhaps particles of helium) having enormous velocities, but small masses. They are slightly deflected by a strong magnetic or electric field.

ALVEOLAR (Alveola)—A pit or depression in the surface of an organ (canals, ducts, passages).

AMACRINE—A term applied to a nerve cell entirely devoid of axis-cylinder processes.

AMINO ACID—An acid in which a portion of the non-acid hydrogen has been replaced by the amino group NH_2.

AMMONIUM—A hypothetic strongly alkaline base (NH_4) existing only in combinations.

AMPHOTERIC—Having the power of altering both red and blue test paper, i. e., that is having acid and alkali properties.

ANABOLIC—Something heaped up, constructive metabolism.

ANÆMIA—A deficiency of blood or of red corpuscles.

ANÆROBIC—Able to live in the absence of free oxygen, without air.

ANÆSTHETIC—A substance producing a state of insensibility.

ANAL—Pertaining to the anus.

ANALGESIA—Insensibility to pain.

ANALOGY—Resemblance or likeness between things.

ANAPHYLAXIS—The condition of decreased resistance to the action of a drug.

ANASTOMOSIS—The junction of vessels or hollow organs.

ANATOMICALLY—Relating to the anatomy, or dissection.

ANGIONEUROSIS—Neurosis of the blood vessels.

ANILINE—An oily poisonous basic liquid ($C_6H_5NH_2$), obtained by the distillation of indigo and used for coloring.

ANION—An electro-negative element.

ANKLE-CLONUS—A succession of rhythmic muscular contractions in the calf of the leg when the foot is suddenly flexed by pressure upon the sole.

ANODE—The positive pole of a galvanic battery.

ANTIBODIES—The characteristic constituents of the blood and fluids of immune animals.

ANTIGENIC—The property of a substance which when inoculated into the blood is capable of causing the production of antibodies.

ANTILYTIC—Opposed to cell destruction.

AORTA—The main arterial trunk.

APICAL—Pertaining to the apex—the point of maximum impulse of the heart against the chest wall.

APLASTIC—Structureless—not plastic.

ARACHNOID—Resembling a web.

ARTERIOLES—A small artery.

ARTIFACT—A structure or appearance in a tissue or cell due to death, or the use of reagents—not present during life.

ASCARIS—A genus of parasitic round worms.

ASPHYXIA—Apparent death or suspended animation in living organisms due to deficiency of oxygen and excess of carbon-dioxide in the blood.

ATOM—The smallest particle of an element which can exist either alone or in combination with similar particles of the same or of a different element.

ATROPINE—Active principle of belladonna ($C_{17}H_{23}NO_3$).

AUTO-GENESIS—Spontaneous generation.

AUTO-GENETRIC-REGENERATION — A spontaneous repair or regrowth of tissues.

AUTO-REGENERATION — Self-repairing of lost tissues.

AXIATION—Pertaining to the axon.

AXIPETAL—In a direction towards the axone.

AXON—The axis of the vertebrate body or skeleton, represented by the bodies of the vertebræ or by the notochord. The Axis-Cylinder process of a nerve cell (also Axone).

B

BARIUM—A metal of the alkaline group. (Ba.)

BARIUM-PLATINOCYANIDE — A compound of barium cyanide and platinum. ($BaPt(CN)_4H_2O$).

BASE—Chief substance of a mixture. In chemistry the OH radical of a compound.

BETA-PARTICLES—See Beta-Rays.

BETA-RAYS—Penetrating rays readily deflected by a magnetic or electric field emitted by radio-active substances, as radium; they consist of negatively charged particles or electrons apparently the same in kind as those of the cathode rays, but having much higher velocities (35,000 to 180,000 miles per second).

BIFURCATION—Dividing into two branches.

BILATERAL—Two-sided.

BIOELECTRIC—Electricity in connection with living organisms.

BIO-RADIO-ACTIVITY — Radio-activity in connection with living organisms.

BIPOLAR—Having two poles.

BLASTODERM—Germinal membrane of an ovum.

BOLOMETER—An instrument used to measure the amount of radiant energy which falls upon it.

BUCCAL—Pertaining to the bucca or cheek.

BUFFER—Something serving to deaden a shock, or to bear the brunt of opposing forces.

C

CADMIUM-TUNGSTATE — Combination of the metals, cadmium and tungsten.

CALAMUS-SCRIPTORIOUS — The lower or posterior part of the floor of the fourth ventricle of the brain which narrows to a point.

CALCIUM—A metal. The basis of lime. (Ca.)

CAPILLARY—A minute blood vessel. Like a hair.

CAPILLARY ELECTROMETER—An electrometer in which the capillary effect produced is used as a measure of very small quantities of electricity, or rapid changes of potential.

CARBOHYDRATES—Any of a group of neutral compounds including the sugars, starches, cellulosis, etc., composed of carbon, hydrogen and oxygen.

CARBON-DIOXIDE—A heavy colorless, irrespirable gas (CO_2), extinguishing flame. Popularly called carbonic acid gas.

CARBON-MONOXIDE—Colorless, odorless gas (CO).

CARBOXYL—The univalent radical CO.OH, the characteristic group of almost all the organic acids.

CARDIAC—Of, pertaining to, or situated near the heart.

CARTILAGE—A non-vascular elastic tissue softer than bone. Gristle.

CASEIN—A precipitate of the milk of various animals. A proteid.

CATABOLISM—The retrograde chemic changes in the tissues of the body.

CATALYST—See Catalyzer.

CATALYZER—(Chem.) A third unaffected substance which promotes a chemic reaction by its presence. (Med.) Alterative medicine.

CATHODE—The negative terminal of an electric source.

CATION—An electro-positive element.

CAUSTIC SODA—Sodium Hydroxide NaOH).

CELIARY—Pertaining to the belly.

CELL—The structural unit of which animals and plants are built. A small protoplasmic mass usually nucleated.

CENTRIFUGAL—Receding from the center.

CENTRIFUGE—An impression sent from a nervous center outward toward the muscle or muscles by which motion is produced.

CENTRIFUGE TUBE—See Centrifuge.

CENTRIPETAL — Proceeding directly toward the center.

CENTRIPETALLY—See Centripetal.

CENTROSOME—A rounded body alongside the nucleus of a cell, that is undergoing karyokinesis.

CEPHALIC—Pertaining to the head.

CEREBELLAR—Pertaining to the cerebellum.

CEREBELLUM—The inferior part of the brain lying below the cerebrum and above the pons and oblongata.

CEREBRAL—Relating to the brain.

CERVICAL—Pertaining to the neck, or cervix.

CHLORIN—A non-metallic gaseous element (Cl).

CHOLESTERIN—A white fatty alcohol found in the blood and nerve tissues and bile ($C_{26}H_{43}OH$).

CHOLINE—An oxygen ptomaine ($C_5H_{15}NO_2$).

CHORDA TYMPANI — The tympanic nerve or nerves of the middle ear cavity.

CHOROID—The second lining membrane of the eye.

CHROMATE—A basic salt of chromic acid.

CHROMATIN—A protoplasmic substance found in the nucleus of the cells which stain deeply with basic stains; for example, carmine.

CHROMOGEN—A colorless body producing pigment.

CHROMOPHIL—Any structure easily stained.

CHRONOLOGY — The science which treats of measuring time by regular divisions or periods, and which assigns to events or transactions their proper dates.

CILIA — The eyelashes. Hair-like processes of certain cells. (Ciliated epithelium.)

CILIO-SPINAL—Pertaining to the ciliary body and the spinal cord.

CLEFT—A fissure or crevice.

CLONIC—Applied to spasms with alternate relaxations.

COAGULATED—Clotted or curdled.

COCAINE—A bitter crystalline alkaloid ($C_{17}H_{21}O_4N$), obtained from cocoa leaves and much used as a local anæsthetic.

COCCYGEUS—Pertaining to a muscle arising from the ischium and lesser sacrosciatic ligament and inserted into the coccyx and sacrum.

COCCYX—The last four consolidated vertebræ of the spinal column.

CŒLIAC—Pertaining to the cavity of the abdomen.

COITUS—Sexual connection.

COLATION—The operation of straining.

COLLATERAL—Accompanying or aiding.

COLLOID—A non-crystallizable or organic substance. Blue-like.

COMBINING CAPACITY—See Valence.

COMMISSURE—A joining or uniting.

COMPLEX—An aggregate of parts; composed of two or more parts.

CONDENSER—An instrument for compressing air or gases. An instrument for concentrating electricity, by the effect of induction, between conducting plates, separated by a non-conducting plat or dielectric.

CONDUCTIVITY—The capacity for conducting.

CONJUGATED—Coupled.

CONJUNCTIVA—The mucous membrane of the eye.

CONSTRICTION—A drawing together in one part.

CONTACTUAL—Of or pertaining to contact.

CONTORTED—Twisted.

CONUS—A cone. A posterior protrusion of the cornea of the eye.

CONVECTION—A process of transfer or transmission, as of heat, by means of currents in liquid or gases resulting from changes of temperature and other causes. Distinguished from conduction and radiation.

CONVOLUTING — CONVOLUTION—CONVOLUTED—A folding upon itself of any organ.

CORNU—A horn-shaped structure.

CORONARY—Encircling, as a vessel, or nerve.

CORPUSCLES—A minute body, a cell for instance, corpuscles of the blood.

CORTEX—In general the outer or superficial part of any organ, such as the external gray layer of the brain.

CORTICAL—Of or pertaining to the cortex.

CORTICO (Cortical)—Pertaining to cortex.

CRANIAL—Pertaining to the cranium.

CREATINE—A nitrogenous constituent of muscle ($C_4H_9N_3O_2$).

CREMASTERIC—A thin muscle consisting of loops of fibers derived from the internal oblique muscle and descending with the spermatic cord, which serves to draw up the testicle.

CROOKE'S TUBE—A highly exhausted vacuum tube used in producing X-rays.

CRURAL—Pertaining to the crura or legs.

CRYPTOGAM—A flowerless, seedless plant.

CUNEUS—A wedge shaped part as the cuneate lobe of the cerebrum.

CURARE—A violently poisonous vegetable extract, paralyzing the motor nerves; the arrow poison of South America.

CUTANEOUS—Pertaining to the skin.

CYST—Membraneous sacs containing fluid.

CYTOPLASM—The watery ground substance of the protoplasm as opposed to the granular contents.

D

DECREMENT—A process of becoming gradually less.

DEFÆCATION—The evacuation of the bowels.

DEMARCATION—Act of settling a distinction.

DENATURATION—Changing the nature of.

DENDRITE—A protoplasmic process of a nerve cell—tree-like.

DENDRON—See Dendrite.

DENTICULATION—Very small tooth-like projections.

DERMATITIS—Inflammation of the skin.

DEXTRIN—A soluble gummy substance obtained from starch.

DIALYZER—An instrument for performing dialysis—the separation of crystalloids and colloids in solution by means of their unequal diffusion through certain natural or artificial membranes.

DIFFERENTIAL—Denoting unlikeness. In medicine, differential diagnosis, the determination of the distinguishing characteristics as between two similar diseases or conditions. In electricity, one of two coils of conducting wire so related to one another or to a magnet or armature common to both that one coil produces polar action contrary to that of the other.

DIGASTRIC—Having two bellies. D. muscle. D. nerve.

DIPHASIC—Pertaining to, or having two phases.

DISINTEGRATE—To separate into integral parts; slow waste.

DISSOCIATION—The process by which a compound body breaks up into simpler constituents.

DISTAL—Away from the center.

DIVALENT—Having the valence of two. (See Valence.)

DIVERTICULUM—A blind tube or sac branching off from a cavity.

DUODENUM—The first part of the small intestine.

DURA MATER—The outer membrane of the brain and spinal cord.

DUROMETER—An instrument for measuring hardness, consisting essentially of a small drill working under a given pressure.

DYNAMIC—Strong or active.

E

ECTOPLASM—An external, or cortical modified layer of protoplasm in a cell. It is clear and hyaline and firmer than the inner layer or endoplasm.

EDEMA—An accumulation of serum in the cellular tissue.

EFFERENT—Conveying from the center, as a nerve.

ELASMO-BRANCH—Pertaining to the elasmo-branchii.

ELASMO-BRANCHII—A sub-class of fishes having the skeleton mainly cartilaginous.

ELECTRODE—That part of any electric apparatus designed to be applied to the body.

ELECTROLYSIS—Dissolution of a compound body by electricity.

ELECTROLYTE—A compound decomposable, or subject to decomposition, by an electric current.

ELECTROLYTIC—Pertaining to electrolysis.

ELECTROMOTIVE—Producing or tending to produce electricity or an electric current; causing electrical action or effects.

ELECTRON—One of those particles having about one-thousandth the mass of a hydrogen atom, which are projected from the cathode of a vacuum tube, as the cathode ray, and from radio-active substances as the beta-rays. Electrons are all of one kind, so far as known, and probably are the ultimate constituents of all atoms.

ELECTROSCOPE—An instrument for ascertaining the presence of static electricity.

ELEMENT—An ultimate constituent.

ELLIPSOIDS—A surface all plain sections of which are ellipses or circles.

EMANATION—A flowing forth; that which proceeds from a body.

EMBRYO—A fecundated germ up to the fourth month.

ENDONEURIUM—The delicate connective tissue around nerve fibers.

ENTERICUS—Diseases or agents affecting the internal canal.

ENZYME—An unorganized hydrolytic ferment.

EPIBLAST—The outer layer of the blastoderm.

EPICRITIC—Pertaining to the return of a normal condition; said of the return of full sensibility in a nerve after an injury.

EPIDERMIC—Pertaining to or arising from the epidermis or skin.

EPIDERMIS—The outer layer of the skin.

EPIGASTRIUM—The region over the stomach.

EPIGLOTTIS—A thin lamella of yellow elastic cartilage which ordinarily projects upward behind the tongue.

EPINERIUM—The nerve sheath.

EPITHELIAL—Pertaining to the epithelium.

EPITHELIUM—A cellular tissue covering a free surface lining a tube or cavity, and consisting of one or more layers of cells with scarcely any intercellular substance, so that the cells form practically an unbroken sheet or membrane. They serve, as in the epidermis, to enclose and protect the other parts of the body and they form the most essential part of the sense organs.

EXCISING—Cutting out or off.

EXCITATION—The act of stimulating or irritating.

EXCITO—A combining form denoting connection with or relation to excitation or stimulation, especially to reflex action.

EXCITO-MOTOR — Arousing muscular action.

EXCITO-SECRETORY—Exciting secretion.

EXPIRATORY—Pertaining to expiration or death.

EXTENSOR—A muscle which causes extension of a part.

EXTIRPATION—Thorough excision of a part.

F

FÆCES (Feces)—Excrement; the discharge of the bowels.

FALLACIOUS—Embodying a fallacy; misleading; as arguments or reasoning.

FARADISM—A succession of inductor shocks. The application of induced electric currents in the treatment of diseases.

FASCICULA—Small bundles of fibers.

FATTY ACID — A monobasic acid formed by the oxidation of primary alcohol and having the formula $C_nH_{2n}O_2$.

FIBRILLATION—A localized quivering of muscular fibers.

FIBRILS—A small fiber or filament.

FIBRIN—A white insoluble fibrous proteid formed especially in the clotting or coagulation of the blood.

FIBULA—The small outer bone of the leg.

FILLET—A band of fibers; applied especially to certain bands of white matter in the brain or lobe of the liver.

FISSURE—A groove or cleft.

FISTULA—An abnormal tube-like passage in the body.

FLEXOR—A muscle that bends or flexes apart.

FLUORESCENCE—Power of a body to change wave rate (or color) of light passing through it. A screen coated with materials which fluoresce when exposed to X-rays.

FŒTAL (Fetal)—Pertaining to the Fœtus or Fetus.

FOLLICLES — Small secretory cavity or sac.

FORAMEN—A passage or an opening.

FOSSA—A depression, furrow, or sinus.

G

GALACTOSE — A white crystalline sugar ($C_6H_{12}O_6$).

GALACTOSIDES—A substance yielding galactose by hydrolysis.

GALVANOMETER—An instrument for measuring the intensity of an electric current, as well as detecting its presence or direction.

GAMMA-RAYS—Very penetrating rays not appreciably deflected by a magnetic or electric field, emitted by radium and other radio-active substances. The prevailing view is that they differ from Roentgen rays only in being more penetrating.

GANGLIA—See Ganglion.

GANGLION—A mass of nerve tissue containing nerve cells; a nerve center. Also a mass of gray matter within the brain or spinal cord.

GASTRIC—Pertaining to the stomach.

GASTRIC FISTULA—See Fistula.

GASTROCNEMIUS—The large muscle of the calf of the leg.

GELATIN—A nitrogenous principle obtained by boiling certain animal tissues as cartilage, ligaments, etc.

GENERIC—Pertaining to the same genus or kind.

GLOBULIN—The albuminus constituent of blood corpuscles.

GLOMERULUS—A knot or small tuft of vessels, or capillaries.

GLOSSO-PHARYNGEAL — Pertaining to the tongue, or pharynx.

GLOTTIS—The opening from the pharynx into the larynx.

GLUCOSIDES—A body containing glucose with some organic principle.

GLUTEAL—Pertaining to or in the region of gluteus muscles, buttocks.

GLYCOGEN—An animal starch found in liver and muscles ($C_6H_{10}O_5$). Protoplasm in fungi containing this compound.

GLYCOGENOLYTIC—See Glycogen.

GOLD-CHLORIDE—A compound of gold and Chlorine. Either AuCl or $AuCl_3$.

GRADIENT—Rising or descending by regular degrees of inclination.

GRANULES—Small rounded grain.

GUTTA-PERCHA—The flexible concrete juice of an East Indian tree; it is used as a protective application.

H

HÆMATIN—A brown pigment from hæmoglobin of blood ($C_{34}H_{35}N_4FeO_5$ or $C_{32}H_{32}O_4N_4Fe$).

HÆMIN—Hematin chloride, a crystalline derivative of blood.

HÆMORRHOID—A livid and painful swelling formed by dilatation of a blood vessel at the margin of or within the anus from which blood or mucus is occasionally discharged.

HÆMORRHOIDAL (Hemorrhoidal) — Pertaining to hemorrhoids.

HALLUCINATION—A false perception or image.

HELIUM—An inert gaseous element occurring in the atmosphere of the sun and stars, and in small quantities in the earth's atmosphere.

HEMIPLEGIA—Paralysis of one side of the body.

HEMISPHERE—A half sphere.

HEMOSTATIC—Arresting hemorrhage.

HEPATIC—Pertaining to the liver.

HETEROGENEOUS—Differing in kind and having unlike qualities.

HIBERNATING — Sleeping throughout the winter.

HILUM—A small fissure, notch or depression. A nucleus of a starch grain.

HIPPOCAMPAL—Pertaining to the hippocampus or elevation on the floor of the descending horn of the lateral ventricle of the brain.

HISTOLOGICAL—Pertaining to the study of the intimate structure of tissues.

HISTOLOGIST—One versed in Histology. (See Histological.)

HOMOGENEOUS—Having the same nature.

HORN—A substance composed chiefly of keratin.

HYDROGEN—A gaseous element, colorless, tasteless, odorless, inflammable and lighter than any known substance. H.

HYDROLYSIS—A chemical process of decomposition involving addition of the elements of water.

HYDROXYL—The univalent radical of OH, consisting of one atom of hydrogen and one of oxygen. It is a characteristic part of bases, alcohols, etc.

HYOID—Designating a bone or several connected bones situated at the base of the tongue.

HYPEREMIA — Excessive amount of blood in any part of the body.

HYPERTROPHY—Abnormal increase in the size of a part or organ.

HYPOTHESIS—A supposition or theory.

I

ILEUM—The lower half of the small intestine.

ILIAC—Dorsal bone of the pelvis.

IMBIBITION—The absorption of fluids.

IMPINGE—To thrust or strike against; to collide with.

INANITION — Emptiness. Exhaustion from starvation.

INDUCTION—The electric influence exerted by neighboring bodies.

INFRA-RED RAYS—Pertaining to or designating that part of the spectrum lying outside of the visible spectrum at its red end. Its rays are invisible and less refrangible than light rays.

INHIBITORY—Having the power to restrain.

INNERVATE—To discharge nervous force, or the function of the nervous system.

INOSITE—A white crystalline substance ($C_6H_6(OH)_6$) existing in three optically different modifications. The inactive variety is found in certain tissues, especially in the muscles of the heart and lungs.

INSPIRATORY—Pertaining to inspiration or the inhalation of air into the lungs.

INTERCELLULAR—Between cells.

INTERFIBRILLAR—Between fibrils.

INTERNUNCIAL — Communicating or transmitting impressions between different parts of the body, as nerves.

INTERSTICES—Spaces, intervals, pores.

INTERSTITIAL—Lying or placed between.

INTRACELLULAR—Within a cell.

INTRACRANIAL—Within the skull.

ION—One of the electrified particles into which according to the electrolytic dissociation theory the molecules of electrolytes are divided by water and other solvents. An ion consists of one or more atoms and carries a unit charge of electricity, 3.4×10^{-10} electro-static units (see Electron), or a multiple of this. Those which are positively electrified (hydrogen and the metals) are called cations; negative ions (hydroxyl and acidic atoms or groups) are called anions.

IONIZATION—Act or process of ionizing.

IONIZE—To separate or concert into ions.

IRIS—The colored membrane of the anterior part of the eye.

ISCHIUM—The inferior part of the hip bone.

ISODYNAMIC—Having equal force. (Foods) Those that produce an equal amount of heat in undergoing the chemic changes of digestion.

ISOTHERMAL—Of equal temperature.

J

JEJUNUM—The middle division of the small intestine, between the duodenum and the ileum.

JUGULAR—Pertaining to the throat or neck as the jugular vein.

JUXTAPOSITION—In close relationship.

K

KARYOKINESIS—Indirect cell division. (Mitosis.)

KATABOLIC—Pertaining to katabolism. The retrograde chemic changes in the tissues of the body.

KEPHALIN—A series of substances occurring in brain tissues.

KERATIN—The basis of horny tissues, used to coat enteric pills.

KOLLIKER—Referring to the fibrous layer which is the connective tissue forming the substantia propria of the iris.

L

LABILE—Gliding from place to place.

LACTIC—Pertaining to milk.

LAMELLA—A thin plate or scale.

LARYNGEAL—Pertaining to the larynx.

LARYNX—The upper part of the windpipe or organ of voice.

LECITHIN—Any of several complex waxy crystallizable substances widely distributed among animal and vegetable products, and especially conspicuous in the brain and nerve tissue in the yolk of eggs and in the white blood corpuscles ($C_{44}H_{90}NPO_9$).

LEMNISCUS—(Fillet) A band of fibers especially applied to certain bands of white matter in the brain.

LEVATOR ANI—A muscle supporting the rectum, vagina, etc.

LEVATOR PALATI—A muscle raising the soft palate.

LEYDEN—(Cells) Large epithelioid cells found in the anterior horns of the spinal cords, in inflammatory affections of the cord. (Jar) Elec. A glass jar used to accumulate electricity.

LINES OF FORCE—A line in proximity to a magnet or electrical conductor carrying current, so drawn that any point in it is tangential with the direction of a short compass needle held at the point. The intensity of different parts of the field is conventionally indicated by the number of lines per unit area.

LINGUAL—Shaped like or pertaining to the tongue.

LIPOIDS—Any one of a group of organic substances insoluble in water. Fat-like.

LOBE—A rounded division of an organ.

LYMPH—A weakly alkaline, nearly colorless coagulable fluid contained in the lymphatic vessels. A fiberless material exuded from the blood vessels in inflammation.

LYSIS—A gradual decline of a disease, especially fever.

M

MAGNETIC FIELD—Any space through which magnetic influence is exerted.

MALAPTERURUS—Pertaining to the cheek or sides of the head.

MARROW—A fatty substance in the cavity of a long bone.

MASTICATION—Is the act of grinding or crushing as with the teeth and prepare for swallowing and digestion as food.

MAXILLARY—Pertaining to the upper and lower jaws.

MAXIMAL—Highest or greatest.

MEDIAN—Being in the middle or occupying an intermediate position.

MEDULLA OBLONGATA—The large portion of the spinal cord in the cranium.

MEDULLATED—Having a medullated sheath—said of nerve fibers.

MEMBRANE—The external coat of blood vessels. Any thin, soft, pliable sheet or layer of animal or vegetable tissue.

MENINGEAL—Pertaining to the membranes of the brain and spinal cord.

MENINGES—The three membranes which envelop the brain and spinal cord.

MENINGITIS—Inflammation of the meninges.

MESENTERIC—Of or pertaining to a mesentery.

MESENTERY—The peritoneal attachment of the small intestine.

MESOBLASTIC—The middle germ layer of the embryo.

METABOLISM—A change in the intimate condition of cells, constructive or destructive.

METAPHYSICS—Those things which relate to external nature, after physics—beyond, after.

METHYL—An organic radical (CH_3).

METHYLENE—The radical base of a series of hydron-carbon compounds (CH_2).

MICTURITION—The act of voiding urine.

MITRAL—Designating or pertaining to the valve (the mitral valve) which guards the left auriculo-ventricular orifice of the heart and prevents the blood in the ventricle from returning to the auricle.

MNEMONIC—Assisting or intending to assist memory.

MOBILE—Movable.

MODALITIES—A matter of mode or method.

MOIETY—One of two equal parts.

MOLECULE—The smallest portion of a compound which retains identity in character with the substance in mass. A unit of matter.

MONATOMIC—Consisting of or saturating one atom.

MONOCHROMATIC—Having but one color.

MOOT—Subject to argument or discussion.

MORPHOLOGICAL—Pertaining to the science of the form and structure of organisms.

MOSAIC—Composed of various materials or ingredients; M. disease, a destructive disease of tobacco, characterized by the appearance of yellow-mottled leaves.

MOTOR—A source of mechanical power; M. impulse, applied to nerves or muscles that which transmits and causes movement.

MUCOSA—A mucous membrane.

MULTIPOLAR—Having more than two poles.

MUSCARINE—A crystalline alkaloid ($C_5H_{15}O_3N$). It is found in fungi; is tasteless, odorless and very poisonous.

MYELIN—A soft, white somewhat fatty material which in medullated nerve fibers forms a thick sheath (the medullary sheath) about the axis-cylinder; it is a mixture of many substances. Lecithin, cholesterin, cerebin and some proteid matter and fats can be extracted from it.

MYELINATION—The process of acquiring a medullary sheath.

MYELOGENESIS—Pertaining to or produced in the bone marrow.

MYLOHYOID—Pertaining to the hyoid bone and molar teeth.

MYXOMYCETES—A group of ameboid micro-organisms believed at one time to be vegetable, now known to be animal in nature.

N

NERVE—A sinew or tendon. One of the cord-like or filamentous bands of nervous tissue that connect the parts of the nervous system with each other, and with the various organs of the body and conduct the nervous impulses.

NERVE FIBER—(Medullated) A cerebro-spinal nerve fiber the axis-cylinder of which is enclosed in a sheath of myelin. (See Myelin.) (Non-Medullated) A sympathetic nerve fiber destitute of myelin.

NEURILEMMA—The delicate outer sheath of a nerve fiber.

NEUROBLASTS—Embryonic cells from which nerve cells develop. A cell forming nervous tissue.

NEUROGLIA—The reticulated frame work of the substance of the brain and spinal cord.

NEUROKERATIN—A variety of keratin present in nerve tissue, as in the sheath of the axis-cylinder of the medullated nerve fibers. (See Keratin.)

NEURON—The nerve cell inclusive of all its processes.

NEUROSIS—A nervous affection without lesion.

NEUTRAL—Possessing neither acid nor basic properties.

NICOTINE—A poisonous alkaloid of tobacco ($C_{10}H_{14}N_2$).

NITROGEN—A colorless, non-metallic, gaseous element; a main constituent of air.

NODE—An indurated swelling on a tendon or bone.

NODES OF RANVIER—Points where the medullary sheath is interrupted and the neurilemma and axis-cylinder are in contact.

NOMENCLATURE — The system of names used in a particular branch of knowledge or art; especially the names used in classifications as distinguished from other technical terms.

NORMAL SOLUTION—Denoting a solution of such strength that one liter contains one gram atom of replaceable hydrogen or its equivalent.

NUCLEIN—A nitrogenous constituent of cell nuclei. The treatment of disease by nuclein.

NUCLEUS—The essential part of a typical cell and the controlling center of its activity.

NUTRITION—The process of assimilation of food.

O

OBLONGATA—(Medulla) The enlarged portion of the spinal cord in the cranium.

OCCIPITAL—Pertaining to the back of the neck.

OLEIC (Acid)—An acid found in olive, almond and other oils ($C_{18}H_{34}O_2$).

OLFACTORY—Pertaining to the sense of smell.

OPTIMUM—The most favorable condition as to temperature, light, moisture, etc., for the growth and reproduction of an organism.

ORGANISMIC—Pertaining to organism or a living organized being.

ORIENTATION—The change of position exhibited by the various protoplasmic bodies within the cell due to the agency of external influences, as light, heat, etc.

ORIFICE—A mouth or entrance.

OSMIC—Of, or pertaining to osmium (a hard bluish or grayish white metallic element of the crystalline form Os).

OSMOSIS—A diffusion of fluids through membranes.

OVUM—The reproductive cell of a female or animal, or vegetable. An egg.

OXALIC (Acid)—An acid obtained by the action of nitric acid on sugar and starch ($C_2H_2O_4$).

OXIDATION—The combining with oxygen.

OXYGEN—A colorless, tasteless, odorless chemically active gaseous element occurring in the free state in the atmosphere (O).

OZONE—A faintly blue gaseous substance obtained by the silent discharge of electricity in air or oxygen and by other methods (O_3).

P

PANCREAS—A racemose gland in the abdomen; the sweetbread.

PANCREATIC—Relating to the pancreas.

PARACENTRAL—Near a center.

PARALLELISM—Quality or state of being parallel. Resemblance, similarity.

PARAMYOSINOGEN—One of the proteids of muscle-plasma.

PARATOID—Near the ear. The paratoid gland.

PARIETAL—Pertaining to a wall.

PARS INTERMEDIA—An intermediate part.

PARTURITION—The act of giving birth to young.

PASTILLES—A lozenge; a sugared confection.

PATELLA—A round sesamoid bone in front of the knee.

PATHOGENESIS—The origin and development of disease.

PATHOLOGY—The science of disease.

PEDUNCLE—A supporting part.

PEPSIN—A proteolytic ferment found in gastric juices.

PEPSIN-HYDROCHLORIC — Designating the acid supposed to be formed by the union of pepsin and dilute hydrochloric acid.

PEPTOGENS—A substance, as dextrin or meat extract, which stimulates the secretion of pepsin.

PERINEURIUM—The connective tissue sheath that surrounds a bundle, or finiculus, of nerve fibers.

PERIPHERAL—Relating to periphery.

PERIPHERY—The circumference or boundary line.

PERISTALSIS—The vermicular motion of the bowels.

PERITONEUM—The serous membrane that lines the cavity of the abdomen.

PERONEAL—Of or pertaining to the fibula; near the fibula.

PHARMACOLOGY—The science of the nature and action of drugs.

PHARYNX—Musculo-membraneous sac behind the mouth.

PHASE—Any one of different and varying appearances of an object. In electricity a single alternating current is termed a single phase current. Magnitudes whose maximum values are simultaneous are said to be of the same phase or to be in phase.

PHOSPHATIDES—An organic compound containing one or more phosphoric acid radicals.

PHOSPHOROUS—A non-metallic element of the nitrogen group, usually obtained as a white or yellowish translucent, waxy crystalline substance with a disagreeable smell, and a faint glow in moist air (P).

PHRENOLOGY—The science of character reading from cranial conformation.

PHYLOGENETICALLY—Pertaining to the development of a group or species as distinguished from individual development.

PHYSICAL—Pertaining to physics or the body.

PHYSIOLOGIC—Pertaining to physiology or the science of the functions of the body.

PHYSIOLOGY—See Physiologic.

PIA MATER—The vascular membrane enveloping the entire surface of the brain and spinal cord.

PIGMENT—An organic coloring matter.

PILOMOTOR—Moving the hairs.

PINNATE—Feather-like.

PITUITARY — Secreting mucus or phlegm, as the pituitary gland.

PLACENTA—The flat, round, spongy body forming the organ of nutrition for the fetus. The afterbirth.

PLANTAR—Pertaining to the sole of the foot.

PLASMA—The fluid part of the blood and lymph.

PLATINOCYANIDE — With potassium cyanide and barium cyanide, soluble platinocyanides ($K_2Pt(CN)_4$, $3H_2O$ and $BaPt(CN)_4$,$4H_2O$) are formed.

PLELÆDES—Pertaining to a group of seven.

PLEXIFORM—Resembling a plexus.

PLEXUS—A network of nerves or veins.

PLURICELLULAR — Having many cells.

PLURIVALENT—Having more than one valence.

PNEUMOGASTRICS—Pertaining to the lungs and stomach.

POIKILOTHERMIC—Adapting the bodily temperature to that of the environment.

POLARITY—Quality or having opposite poles. The condition of analectrotonun and catelectrotonos in a nerve.

POLYATOMIC—Having several atoms in the molecule.

POLYDYNAMISM—Science of moving force. (Poly, meaning many.)

PONS—A process or bridge of tissue connecting two parts.

POSTCEPHALIC—Behind the head.

POSTERIOR—Later or coming after.

POTASSIUM—A soft light silver-white metal of the alkali group occurring abundantly in nature, but always in combination.

POTENTIAL—Referring to electro-motive force. The degree of electrification as referred to some standard as that of the earth.

POTENTIAL-GRADIENT — See Potential and Gradient.

POTENTIOMETER—An instrument for measuring or comparing electrical potentials or electro-motive forces.

PRECIPITATE—A substance separated from a solution in a concrete state in consequence of some chemical or physical change.

PRECORTICAL—See Cortical.

PRIMORDIAL—Originally or earliest form in the growth of an individual or organ; primitive. P. cell, a cell without a cell wall.

PROPAGATION—The spreading abroad or extension of anything. Reproduction.

PROTEAN—Exceedingly variable, readily assuming different shapes or forms, as an amœba is a protean animalcule.

PROTEIN—An organic substance consisting essentially of C, H, N, O, and S; characteristic of living matter. Albumin.

PROTEOLYSIS—Cleaving or hydrolysis of proteids with formation of simpler and soluble products, as indigestion.

PROTOPATHIC—Primary; relating to the first lesion. Pertaining to the first evidence of a return of function; said of the appearance of imperfect sensibility, in a nerve after an injury.

PROTOPLASM—Primitive organic cell matter; germinal matter.

PSEUDOPOD—A temporary protrusion of retractile process of the protoplasm of a cell, especially of a unicellular organism or a free cell.

PSYCHIATRY—The treatment of mind disease.

PSYCHIC—Of or pertaining to the human soul, or the living principle of man.

PSYCHOLOGY—The science of mind.

PULMONARY—Pertaining to the lungs.

PYRAMIDAL—Shaped like a pyramid.

Q

QUADRICEPS—A large muscle of the thigh.

QUANTUM—Amount or quantity.

QUININE—A white bitter alkaloid used as a tonic and anti-periodic. $(C_{20}H_{24}N_2O_2)$. $3H_2O$.

R

RADIANT—Diverging from a center as rays.

RADICAL—A group of atoms replaceable by a single atom or remaining unchanged during a series of reactions, hence conveniently as playing the part of a single atom. A form of treatment meant to destroy a disease.

RADIO-ACTIVITY—The power of spontaneous emission of rays having chemic and electric properties.

RAMI—Branches of arteries or veins or nerves.

RAMUS COMMUNICANS — A branch from the anterior root of spinal nerves to the sympathetic chain of ganglia.

REAGENT—Anything producing a reaction.

REFRACTION—The deviation of light on passing through a medium of different densities.

REFRACTORY — Resisting treatment. Unsusceptible to disease.

REFRANGIBLE—Capable of being refracted, as rays of light.

REPETITIVE—Repeating.

RESONANCE—Act of resounding.

RESPIRATION—Inspiration and expiration of air by the lungs. Breathing.

RESPIRATORY—Pertaining to respiration.

RETICULUM—A network. The network of denser substance visible in the protoplasm, both of the cell body and nucelus of many cells, and according to the reticular theory regarded as an essential structural part of the protoplasm.

RETINA—Internal membrane of the eye, the expansion of the optic nerve.

ROENTGEN RAYS—See X-rays.

S

SACRAL—Belonging to the sacrum.

SACROSCIATIC—Of or pertaining to the sacrum and the hip; as the sacrosciatic ligaments which connect the sacrum and the hip bone.

SACRUM—That part of the vertebral column which is directly connected with, or forms a part of, the pelvis. In man it forms the posterior wall of the pelvis.

SALIVARY—Pertaining to the saliva.

SALT—Any of a class of compounds formed when the acid hydrogen of an acid is wholly or partly replaced by a metal or a metal-like radical. As a class salts dissociate readily in solution.

SATURATION—The condition of holding in solution all of a solid capable of being contained.

SCAPULA—A large, flat, triangular bone of the shoulder.

SCIATIC—Of or pertaining to the hip; in the region of or affecting the hip.

SCLEROSIS—Induration and overgrowth of the connecting tissues of an organ. Hardening.

SECRETORY — Secreting; connected with or promoting secretion.

SECTION—To cut off or separate.

SELENIUM—A non-metallic element resembling sulphur.

SELLA-TURCICA—Pituitary fossa of sphenoid bone.

SEMI-LUNAR—Crescent-shaped.

SENSORY—Applied to nerves and nerve fiber carrying to a nerve center impulses resulting in sensation.

SERUM—The fluid constituent of the blood separated by coagulation.

SIMULATE—To assume the mere appearance of without the reality.

SINUS—A hollow cavity, recess or pocket.

SKELETAL—Pertaining to the skeleton.

SODIUM—A soft, waxy, silver-white metallic element of the alkali group occurring abundantly (always in combination) as in common salt, etc. (Na).

SODIUM-CHLORIDE — Common salt (NaCl).

SOMÆSTHETIC—Pertaining to the body sensations.

SPECTROPHOTOMETRIC — Pertaining to the spectrophotometer, an instrument for comparing the intensities of the corresponding colors of two spectra.

SPECTROSCOPE—An instrument used for forming spectra.

SPECTRUM—A color band from a ray of decomposed or dispersed light.

SPERMA—Denoting seed.

SPHENOID—Wedge-shaped. S. bone, one of the cranial bones at the anterior base of the skull, articulating with all the other bones of the head.

SPHENOPALATINE—Pertaining to the sphenoid and palate bones.

SPHINCTER—A muscle constricting an orifice.

SPHINCTER-IRIDIS—See Iridis or Iris.

SPLANCHNIC—Pertaining to the viscera.

SPORES—Any germ or reproductive element less organized than a true cell; reproductive body of a cryptogram.

STATIC—At rest, an equilibrium. Elec. The electricity of stationary charges produced by rubbing together unlike bodies such as glass and silk.

STELLATUM—Star-shaped.

STERILIZE—To destroy the germs.

STIMULI—That which excites or stimulates an organ.

STRATIFICATION—The arranging in layers.

STRIATED—Marked with furrows.

STRING-GALVANOMETER—An instrument for measuring oscillating currents.

STRYCHNINE—A very poisonous alkaloid ($C_{21}H_{22}O_2N_2$), obtained from various species of plants.

SUBCLAVIAN—Under the collarbone.

SUBCUTANEOUS—Under the skin.

SUBLAXATION—A slight dislocation.

SUBMAXILLARY—Beneath the inferior maxilla. The lower jaw.

SUBSTRATUM—That which underlies or supports something.

SUCCAGIGUES—A substance stimulating the flow of a digestive juice, particularly the gastric juice.

SUCCUS—Juice.

SULPHATE—A salt or ester of sulphuric acid.

SUPRARENAL—Above the kidney.

SUPRASENSORY—Highly sensitive.

SUTURED—Stitched or tied together, as a seam.

SYMPATHETIC—(Nerve) One of a system distributed to the blood vessels and viscera.

SYMPTOMATIC—Pertaining to a symptom.

SYMPTOM—A phenomenon of a disease usually subjective in character.

SYNAPSES—The anatomic relation of one neuron with another.

SYNAPTIC—See Synapses.

SYNERGIC—Exhibiting or relating to energy.

SYNTHESIS—The formation of a compound by uniting its elements.

T

TACTILE—Pertaining to the sense of touch.

TELEOSTEAN—Pertaining to Teleostei, a sub-class or other division of fishes, including ordinary fishes. This group includes most modern fishes.

TERPENE—Any hydro-carbon with the formula $C_{10}H_{16}$. A prominent constituent of many volatile oils.

THERMAPEUTICS — The branch of medical science concerned with the application of remedies and the treatment of disease.

THERMIC—Pertaining to heat.

THERMIC-RAYS—Heat rays.

THERMO-COUPLE—A thermo-electric couple. (See Thermopile.)

THERMOPILE—An apparatus consisting of a number of thermo-electric couples as of antimony and bismuth or of copper sulphide and german silver, combined so as to multiply the effect. It is used to generate electric currents for certain purposes and also in a very sensitive form for determining slight differences in temperature.

TOPOGRAPHICAL—Pertaining to topography, or a description of the regions of the body.

TOXIC—Poisonous.

TRACT—Any one of the columns of white matter of the spinal cord.

TRANSMUTATION—Change of one species into another. The change from one nature, form or substance into another.

TRAUMA—A wound or an injury.

TRIMETHYLAMINE—A liquid ptomaine from herring brine (C_3H_9N).

TRIVALENT — Having a valence of three.

TROPHIC—Pertaining to nutrition. Those nerves believed to influence nutrition.

TRUNCI-VAGUS—The main nerve of the stomach and lungs.

TRYPSIN—A proteolytic ferment of pancreatic fluid.

TYMPANUM—The middle ear cavity.

U

ULNAR—Pertaining to the ulna or the large bone of the forearm.

ULTRA-VIOLET LIGHT — Outside the visible spectrum at its violet end; rays more refrangible than the extreme violet rays.

UNILATERAL—Affecting but one side.

UNIPOLAR—A cell with one process. Having but one pole.

UNIVALENT—Having the valence of one.

UREA—The chief solid constituent of urine, CON_2H_4.

URO-GENITAL—Designating the organs or functions of excretion and reproduction.

UTERO—The Womb.

V

VACUUM—A space exhausted of air.

VAGAL—Pertaining to the vagus nerve.

VAGUS—The pneumogastric nerve.

VALENCE—The combining power of an atom as compared with an atom of hydrogen, which has a valence of one.

VASCULAR—Pertaining to a vessel or vessels for the conveyance of a fluid, such as the blood vessels.

VASO-DILATATION—State of expansion of the blood vessels.

VASO-MOTOR—Regulating the tension of the blood vessels.

VENOSITY—Quality or state of venous, or pertaining to veins.

VENTRICLE—A cavity of an organ, especially the chamber or one of the chambers of the heart which receives the blood from an auricle and from which it is forced into the arteries.

VERATRINE—A white crystalline poisonous alkaloid having an acrid burning taste obtained from the root of white or false hellebore, and from sabadilla seed.

VERMICULAR—Worm-like.

VERTEBRATE—Having vertebræ or a spinal column.

VESICULAR—Of or pertaining to the air cells of the lungs.

VIEUSSEN'S ANNULUS—A small nerve passing between the middle and lower cervical or first dorsal ganglions and forming a loop around the sub-clavian artery.

VISCERA—The contents of the body cavities.

VISCERAL—Pertaining to viscera.

VISCOSITY—Property of being sticky.

VOLTAIC—Of or pertaining to galvanic electricity.

W

WHEAL—A raised stripe or ridge on the skin.

WOLFFIAN BODY—An organ of embryonic life situated on each side of the vertebral column, and consisting of series of convoluted tubes opening into a lateral duct.

X

X-RAYS (Roentgen Rays)—Are ether rays or waves having peculiar penetrative power through matter opaque to other ether waves and by means of which photographs may be taken of bones and metallic substances, etc., situated in the tissues.

XANTHINE—A white micro-crystalline nitrogenous compound present in muscle tissue in the liver, spleen, pancreas and other organs ($C_5H_4O_2N_4$).

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